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INSTITUTE OF SCIENCE AND TECHNOLOGY • THE UNIVERSITY OF MICHIGAN
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A survey of CAD/CAM technology applications in the U.S. shipbuilding industry (1983).

R. L. Diesslin

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R. L. Diesslin

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Contract No. MA8D-SAC-01089
IITRI Project K06011

A SURVEY OF CAD/CAM TECHNOLOGY APPLICATIONS IN THE U.S. SHIPBUILDING INDUSTRY (1983)

Maritime Administration
U.S. Department of Transportation
400 Seventh Street
Washington, D.C. 20590

Prepared by:

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January 1984

FOREWORD

This final report, entitled "A Survey of CAD/CAM Technology Application in the U.S. Shipbuilding Industry," covers the work performed under the U.S. Department of Transportation contract number MA80-SAC-01089, IITRI Project number K06011-K005.

The work has been performed by the Engineering Division of the IIT Research Institute under the direction of Project Manager, Edmund R. Bangs, Coordinator of Shipbuilding Research Activities. The Project Administrator was Pamela A. Slechta, Business Analyst; the Principal Investigator and major contributor was Richard L. Diesslin, Research Engineer; and the primary programmer and systems analyst was Raymond Vitkus, Senior Technician; all from the Manufacturing Technology Section at IITRI. Special acknowledgment is extended to Linda M. Bender for initial organization and coordination of the CAD/CAM survey project.

A sincerest expression of thanks goes to all those who participated in filling a CAD/CAM Survey questionnaire (Table 1, Section 1), without whose participation the CAD/CAM Survey would not be possible. Above and beyond the call of duty were those individuals who participated as members of the CAD/CAM Survey Advisory Board and the. shipyards who sponsored their participation (Table 2, Section 1). Finally, a special debt of gratitude is extended to those shipyards who not only took the time to fill out a survey questionnaire but also allowed the research team access to their shipyards and personnel to conduct extensive. shipyard and design agency visits. These shipyards and individuals are not listed within the body of this report due to the confidential nature of these visits, however their participation and cooperation is much appreciated. Special acknowledgment is extended to Mr. Bob Skirkanich of Grumman Data Systems and Charles G. Pieroth of Grumman Advanced Marine Systems for their cooperation on shipyard visits and assistance with coordinating the CAD/CAM Survey and Software Tools Projects.

Respectfully submitted,

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EXECUTIVE SUMMARY

At the onset of the Five-Year National Shipbuilding Productivity Improvement Plan it was decided that, in addition to the plan, a comprehensive benchmark was needed. Therefore a survey of CAD/CAM applications in U.S. shipbuilding industry was established. Eighteen shipyards and four design agencies participated in the CAD/CAM survey by returning a survey questionnaire.

The major sections of this report analyze various areas of CAD/CAM technology application in the U.S. shipbuilding industry. Highlights from the shipyard visits are outlined, voids in the shipbuilding industry's application of CAD/CAM technologies are analyzed, and recommendations and conclusions are made based on survey findings.

The main emphasis to date is management systems. Not all implementations have been successful, but many management systems are evolving into more real-time and near real-time use down to the supervisory and/or foreman level. Computer Aided Design (CAD) drafting systems are quickly becoming the normal mode of operation for drafting. Computer Aided Engineering (CAE) analysis is used primarily to determine the validity of design characteristics and production engineering tolerances and is the fourth most utilized CAD/CAM technology. Automation, where in use, is primarily experimental and therefore is not currently an important factor in ship production.

Planned future implementations are being given the same relative emphasis as these current trends. Functions involving design, engineering and planning activities represent almost three quarters of all current shipyard computerization. Similarly, exactly three quarters of planned future implementations are also primarily in these areas.

If viewed by major CAD/CAM systems applications, shipyards that are strong in one technology are usually strong in others, with few exceptions. Potentially the most significant trend is in computer assisted managemnt systems (cAmss). The top four performers in the management systems category ranked one, three, four, and five in overall CAD/CAM technology application. When viewed. by major shipyard functions, shipyards are quite varied in the manner in which they apply CAD/CAM technologies. Computerization tends to decrease as actual production/erection activities increase or in other words, computerization decreases as the level of planning decreases. Shipyards have a potential for 244 CAD/CAM technology applications and the average coverage of these applications is 31 (13 percent of the potential) per shipyard. Six shipyards had a large margin of computer application above the rest and exhibited greater satisfaction with their CAD/CAM systems (in terms of successfulness rating) than the other shipyards. This may suggest that 50 CAD/CAM applications is the first major threshold from which greater returns are expected. Design agencies experience similar trends as shipyards, however there are only 110 possible applications (vs 244 in the shipyard) due to the different nature of their work (no actual production) and average 14 percent of their potential.

Observation suggests that shipyards (and to some extent design agencies) are at the end of a "wait and see" attitude toward computerization and are about to embark on a more certain, systematic, and accelerated approach to CAD/CAM technology implementation in the near future.

In-house programs represent approximately 30 percent of all software applications and more than half of the shipyards/design agencies surveyed have written substantial in-house programs (these cover most applications but concentrate mostly around management information and control systems). Some unique vendor software applications include time standard generation, sea trial analysis, and group technology analysis.

Systems integration is the largest problem involving software packages. While no systems surveyed are truly integrated, many are interfaced. Computer Aided Design (CAD) is the most interfaced category with links from engineering analysis, N/C process control, shell plate development, and N/C tape verification. Most all interfaces are in-house developed links.

Shipyards report that the top three benefits are leadtime reduction, increased product quality, and improved control of operations. Design agencies have experienced roughly the same benefits and problems as shipyards. Design agencies are much newer at CAD/CAM technology application and are much further-back on the learning curve than most shipyards.

Successful strategic management approaches include upper management support, production oriented planning, planning and production staff cooperation, organizational restructuring to accommodate new methods, and management/worker participation in the work methods restructuring. There are also several tactical and implementation considerations, which are an integral part of successful management approaches, as well as the successful technical approaches needed to carry out the strategic objectives.

The following are some general recommendations based on the CAD/CAM survey findings. Shipyard and design agencies should continue to manage using those techniques that have been proven successful, especially those concerned with strategic management. The shipbuilding industry should continue to lead in its areas of strength. One area that could be of great benefit to the advancement of the U.S. shipbuilding industry is the ability to coordinate, consolidate and communicate among the various shipbuilding related advisory groups. The U.S. shipbuilding industry is moving toward pre-erection outfit planning methods and projects that enhance and/or contribute to this trend and should continue to be encouraged. The shipbuilding industry should continue to be aware of and perform research and development projects in automation. And finally, projects that promote CAD/CAM technology transfer should be encouraged.

While no one shipyard or design agency is clearly ahead of the rest in terms of application of CAD/CAM technologies, it is evident that the U.S. shipbuilding industry is making a serious attempt to modernize through the use of CAD/CAM technology. With effective use of future research and development projects, as well as government incentive programs and the hope for some effective maritime policies from Congress, the U.S. shipbuilding industry is beginning its slow approach toward recovery. It is not a clear path by any means. Even the most judicious use of research projects and CAD/CAM technologies cannot guarantee that the U.S. shipbuilding industry will ever compete effectively in the world market again; however this is its only chance.

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1. INTRODUCTION AND BACKGROUND

Computer Aided Design (CAD) and Computer Aided Manufacturing (CAM) are viable ways of increasing productivity in the shipyard. CAD/CAM encompasses numerous computer technologies, which may be applied to most functions throughout the shipbuilding process.

In planning for future new systems, shipyard management will benefit from the documentation of current CAD/CAM efforts in shipbuilding to the extent that it can identify trends and discuss past successes and failures regarding technology implementation. Th e objective of this project is to provide shipyard management with a comprehensive shipbuilding industry study detailing computer technologies available and their current application to shipbuilding functions including problems encountered, benefits realized, and level of success attained.

1.1 HISTORY AND METHODOLOGY OF THE CAD/CAM SURYEY

At the onset of the Five-Year National Shipbuilding Productivity Improvement Plan toward the end of 1981 it was decided that in addition to the plan, a comprehensive benchmark was needed if the effectiveness of the plan was to be established. Therefore, a venture project to the Five-Year Plan (Maritime Administration) was established to conduct a survey of CAD/CAM applications in the U.S. shipbuilding industry. The task of performing the CAD/CAM survey began as the Five-Year Plan was concluding toward the end of 1982.

At the same time the Ship Production Committee, Technical Panel 4, Design/Production Integration panel (SP-4), was commencing with a project to identify software tools that would enable shipyards and design agencies to improve their programming and integration productivity. This meant that there were two projects being run simultaneously, both involving CAD/CAM Technologies Concern arose over the two projects' scope of work. In a meeting of the two projects' research teams and sponsors, held in Washington, D.C., in January of 1983, it was determined that, in fact, the two projects were complementary in nature and should proceed. However it was determined that they should proceed in a coordinated fashion so that both would be enhanced.

The IITRI and Grumman research teams immediately started to coordinate their efforts. They arrived at a mutual statement (below), which defined their individual scopes of work and the areas of cooperation. In fact, the Grumman and IITRI research teams made three joint visits to shipyards, attended some of each other's advisory board meetings, and had numerous phone contacts to ensure a coordinated effort.

STATUS OF THE SHIPBUILDING CAD/CAM PROGRAM PROJECTS

The two CAD/CAM studies, U.S. Shipbuilding CAD/CAM Survey and SP-4 Software Tools Study, are complementary in nature and both contribute to a greater understanding of the usefulness of computer technology in American Shipbuilding and design activities. The CAD/CAM Survey project deals with CAD/CAM tools as applied to shipbuilding functions and the Software Tools project studies software which will aid in implementing, integrating, and automating software development. A comparison of goals follows:

CAD/CAM Survey Project	Sofware Tools Project
1) To identify and compile present applications of CAD/CAM in the U.S. shipbuilding industry.	1) To determine current plans for software development, purchase, and maintenance in U.S. shipyards.
2) To identify gaps (voids/weaknesses) in U.S. shipbuilding CAD/CAM technology with respect to functional applications.	2) To evaluate existing softvare tools that could automate shipyard software systems development, production, and testing.
3) To identify and recommend ways in which future advancement can be achieved in the U.S. shipbuilding industry.	3) To determine cost savings for application of selected automated software tools.

4) To compile all results into separate reports for use by shipyard management in selection, evaluation and use of computer technology (and software tools).

T o summarize, the CAD/CAM Survey is a view of CAD/CAM applications, present and near term (3-5 years) and the Software Tools Project a view of the software support tools necessary to facilitate CAD/CAM applications.

The Software Tools project uses a series of scenarios to define the potential software development approach options available to managing software development/i integration. The CAD/CAM Survey uses a composite or total view of the functional aspects of U.S. shipbuilding to define the application and future opportunities of computer technology. The use of scenarios and compositing provides for a full understanding of the CAD/CAM options/opportunities and the ways in which they can be implemented by U.S. shipbuilders and design agencies.

The CAD/CAM Survey commenced work in October of 1982 identifying 36 shipyards and design agencies that would be desirable to contact for the CAD/CAM survey and by performing a detailed literature search. This list is shown in Table 1, Shipyards and Design Agencies Contacted for the Survey Questionnaire. Of these, many were contacted initially to become members of the projects advisory board. This group was to serve as council on development of the survey questionnaire and in review of the project plan of action. Table 2 provides a list of the people from the various shipyards and design agencies who served as members in at least one of the two advisory board meetings.

Prior to the first advisory board meeting a rough draft of the survey questionnaire and a plan of action were prepared. The first advisory board meeting was held on December 1, 1982 in Philadelphia. The initial questionnaire was reviewed and enhanced and it was decided that there was a need for a glossary of terms to accompany the questionnaire sent to shipyards and design agencies. The advisory board members realized that the most.important objective of the CAO/CAM survey was to deliver a benchmark study to provide the actual status of computer technologies in the U.S. shipbuilding industry, so they requested that the questionnaire become the only focus until the next advisory board meeting.

The research team contacted each of the 36 shipyards and design agencies individually to ensure that one person from each would take responsibility for handling the survey questionnaire. Then the final version of the CAD/CAM survey questionnaire and glossary were sent out at the end of March, 1983. The final version of both the questionnaire and the glossary can be found in Appendix C and Appendix A, respectively. After approximately two months, those who had not returned the questionnaire were contacted to determine the status of the questionnaire. With the bulk of the questionnaires in by June another advisory board meeting was scheduled in conjunction with the National Computer Graphics Association show in Chicago.

TABLE 1 Shipbuilding and Design Agents Contacted for the Survey Questionnaire

* ALABAMA SHIPBUILDING & DRY DOCK	* LONG BEACH NAVAL SHIPYARD
AMERICAN SHIPBUILDING CO.	MARINETTE MARINE
* AVONDALE SHIPYARDS	* MARYLAND SHIPBUILDING
BATH IRON WORKS	* McDERMOTT
* BAY SHIPBUILDING	* NATIONAL STEEL & SHIPBUILDING CO.
* BETHLEHEM STEEL & SHIPBUILDING Beaumont, TX	NEWPORT NEWS SHIPBUILDING
* BETHLEHEM STEEL SHIPBUILDING Sparrows Point	* NORFOLK NAVAL SHIPYARD
GALVESTON SHIPBUILDING CO.	NORFOLK SHIPBUILDING & DRY DOCK
GENERAL DYNAMICS - ELECTRIC BOAT	* PENNSYLVANIA SHIPBUILDING
GENERAL DYNAMICS- QUINCY	* PETERSON BUILDERS, INC.
* GIBBS & COX	PHILADELPHIA NAVAL SHIPYARD
HEMPLE MARINE	PUGET SOUND NAVAL SHPYARD
* INGALLS SHIPBUILDING	* M. ROSENBLATT 7 SON, INC.
* J J HENRY	* TACOMA BOAT
* J. J. McMULLEN	TAMPA SHIPYARDS, INC.
JEFFBOAT	* TODD PACIFIC SHIPYARDS: San Pedro, CA
* LIVINGSTON	* TODD PACIFIC SHIPYARDS: Seattle, WA
* LOCKHEED SHIPBUILDING	St. LOUIS SHIP Div. Pott Industries

* = Questionnaire received

TABLE 2 The CAD/CAM Survey Advisory Board

R. Price	Avondale Shipyards
G.Lake	Bay Shipbuilding
R. H. Miller	Bay Shipbuilding
B. G. Bohl	Bethlehem Steel Corp.
L. A. Denney	General Dynamics - Quincy
T. F. McCarthy	General Dynamics - Electric Boat
R. Skirkanich	Grumman Data Systems
R. V. Shields	Ingalls Shipbuilding Co.
G. Plancich	J. J. Henry
B. Haskell	J. J. McMullen Co.
J. Renard	Long Beach Naval Shipyard
F. Nigro	Long Beach Naval Shipyard
R. Schaffran	MarAd
F. B. Barham, Jr.	Newport News Shipbuilding
L. M. Bartram	Newport News Shipbuilding
G. O'Keefe	Peterson Shipbuilders, Inc.
R. Lovdahl	Todd Shipbuilding

Preliminary results were prepared based on the 12 shipyard questionnaires received at that point in time. The Advisory Board decided shipyard visits were necessary as well as at least one visit to a design agency to fully interpret the questionnaire statistics. The scope of the survey was then finalized by the Advisory Board and did not include expanding the survey to review CAD/CAM technology applications in other industries that could benefit the shipbuilding industry. The Advisory Board felt that it would reduce the impact of the benchmark study, so the final scope of work directed that U.S. Shipbuilding companies were to be visited and then the report written, once all the questionnaires were received. In fact, the last questionnaire was received in September of 1983 and the actual shipyard visits concluded in October.

The net result is that 18 shipyards and 4 design agencies participated in the CAD/CAM survey by returning a questionnaire, and nine visits were made, eight to shipyards and one to a design agency. This response is quite comprehensive including an invaluable cross section of shipyards and design agencies of all sizes and levels of sophistication

1.2 CAD/CAM

This survey-views CAD/CAM as synonymous with all computer technologies utilized in the manufacturing operations of an enterprise. It is a common misconception to consider a computer aided design drafting system that can generate an N/C program file a CAD/CAM system. This misconception is perpetuated mostly by CAD/CAM system vendors; however, this survey will refer to those systems as merely CAD drafting systems. The surveys definition of CAM includes N/C process control and computer aided engineering, manufacturing technologies, computer assisted management systems, and automation. No true turn-key CAD/CAM systems exist by this survey’s definition. Also it is important to distinguish the term CAD/CAM from the term computer integrated manufacturing (CIM). CAD/CAM is a much broader area than that of CIM because CIM implies a computerized closed loop manufacturing system, or in otherwords heavy integration, and CAD/CAM places no such limitation on computer technologies. There is no dispute that CIM may well be the desired approach to CAD/CAM but it is neither synonymous nor more comprehensive.

1.3 GUIDE TO REPORT CONTENTS

Sections 2 through 4 of this report each correspond to an individual part of the survey questionnaire. Section 2 refers to part I of the questionnaire, which analyzes six major CAD/CAM technology areas across 79 shipyard functions. functions. Section 3 refers to part II of the questionnaire, which involves an evaluation of the software in use in the U.S. shipbuilding industry today. Section 4 refers to part 111 of the CAD/CAM survey questionnaire and it analyzes computer technology benefits and problems. The final section of the report, Section 5, highlights the shipyard visits, the shipyard functional areas that are not using CAD/CAM technologies, and makes recommendations and conclusions based on the survey findings.

2. COMPUTER TECHNOLOGIES AND SHIPBUILDING FUNCTIONS

This section interprets the survey information from part I of the questionnaire, Appendices B and F, and shipyard visits. Shipyards and Design Agencies are analyzed separately and each is reviewed first by relative trends and second by absolute trends. The relative trend analysis reviews the emphasis that the U.S. Shipbuilding industry places on computerization of functional areas (or activities) as a whole. The absolute analysis compares shipbuilding performance to absolute potential for computerization and analyzes each shipyard's/Design agencie's evaluation of their CAD/CAM technology applications (in a composite manner).

The objectives of evaluating computer technologies against shipbuilding functions are to:

- identify CAD/CAM technology trends within the U.S. Shipbuilding industry.
- identify functional CAD/CAM applications
- analyzes strong and weak areas
- provide insight into the current trends
- identify future trends in CAD/CAM applications

Interpreting future trends in this section is particularly informative once one basic concept is clarified. All planned future implementations represent totally new applications since a questionnaire respondent could only elect one rank (+, √, -, N or F) for each of the Part I matrix blanks (79 functional areas across six major CAD/CAM technology areas, refer to Appendix F). If an implementation already existed then future plans could not be indicated. This provides an excellent conservative basis for determining future trends since improvement, modification, and/or replacement of existing applications can be expected in addition to the predicted future trends. This will be primarily true of computer assisted management systems due to constant in-house upgrading, and computer aided design systems due to replacement. Finally, "future" refers to roughly five years ahead so this survey's future trends are focused on the 1983 to 1988 time frame.

2.1 RELATIVE TREND ANALYSIS FOR SHIPYARDS

2.1.1 Current and Future CAD/CAM Relative Trends in Systems Applications

To characterize the emphasis given to each CAD/CAM technology area, Figure 1 cuts across functional/organizational boundaries to review all applications by CAD/CAM technology category and illustrates their relative emphasis. Many turn-key systems and vendor supplied software packages are available in the Computer Aided Design (CAD), N/C Process Control (N/C), and Computer Aided Engineering Analysis (CAE) areas, however, most Computer Assisted Management Systems are homegrown (in-house developed).

By far, the main emphasis to date is management systems. Not all implementations have been successful since 2 percent are considered unsatisfactory. However, the shipyard visits provided strong evidence that the management systems are evolving into more real time and near-real time (e.g. daily status) use down to the supervisory and/or foreman level whereas five years ago there was some doubts in this area.

Computer aided design (CAD) drafting systems have been incorporated at many shipyards within the last five to six years and are quickly becoming the normal mode of operation for drafting. Although many drafting systems have the capability to generate N/C tape files, the Shipbuilding industry rarely uses this option (refer to Section 3.4.3), primarily because hull definition and lofting systems have this feature and were in place before CAD drafting systems. Also, where drafting sytems are primarily generic, hull definition and lofting software is shipbuilding specific and therefore often more user friendly.

N/C finds its use almost exlusively for steel plate cutting and forming with the exception of a few shipyards usage in the machine shop. Since N/C is an integral part of lofting and hull definition software it finds process control/planning applications in design, drafting and engineering functions and tape preparation in production engineering and lofting functions as well as the actual cutting and forming activities within the manufacturing functions.

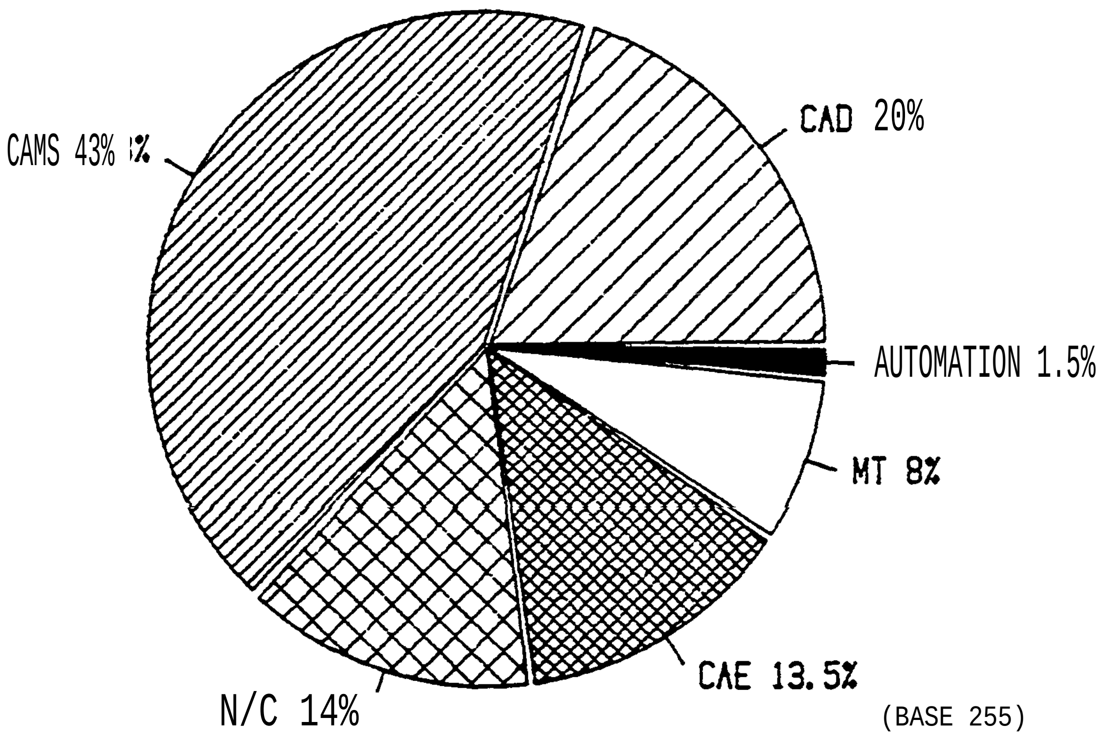

Figure 1. Shipyard Computer Technology Applications by System Type

Computer assisted management systems applications represent 43% of all CAD/CAM technology applications in the U.S. shipyards surveyed. Most of these systems are in-house developed. Computer aided design systems and N/C process control represent the next largest categories of CAD/CAM systems implemented. These are primarily vendor supplied and many are turn-key systems. Computer assisted engineering programs accounted for 13.5% of all CAD/CAM applications and ranged from in-house to government top vendor developed and to time-sharing services. Manufacturing technology and automation represented 8% and 1.5% of the applications, respectively.

Computer aided engineering (CAE) analysis is used primarily to determine the validity of design characteristics and production engineering tolerances. Manufacturing technologies include lofting and parts nesting for part I analysis and therefore contribute primarily to the production engineering activities. Automation, where in use is primarily experimental and therefore is not currently an important factor in ship production.

Future trends shown in Figure 2 are being given the same relative emphasis as current trends. Management systems are continuing to close the loop between planning, scheduling, and actual production/construction functions working toward more and more control over operations. Computer aided design owes its emphasis primarily to shipyards who have yet to implement CAD drafting systems; however, many current users intend to modify or replace systems in such a way as to expand the number of design and engineering applications they can be used for. Manufacturing technology, CAE and N/C will all receive about the same level of attention whereas implementation of automation will be almost non-existent. Possibly the most important manufacturing technology implementations planned are process planning, time standard generation and group technology. An important trend for N/C is its continuing expansion into sheet metal work in the shop activities of U.S. shipyards.

2.1.2 Current and Future Functional Relative Trends in Shipyard Computerization

Figure 3 illustrates the relative emphasis placed on computerization based on Shipayrd functions/activities. Functions involving design, engineering and planning activities represent almost three-quarters of all shipyard computerization. This suggests two observations: 1) the design and planning tasks in ship construction are very involved, thus demanding computer support (e.g. similar to reasons why accounting was computerized early on relative to manufacturing) and (2) that it is difficult to computerize manufacturing and particularly construction/assembly functions. Similarly, exactly three quarters of the planned future implementations, Figure 4, are also in the functions involving-design, engineering, and planning, therefore further supporting these observations.

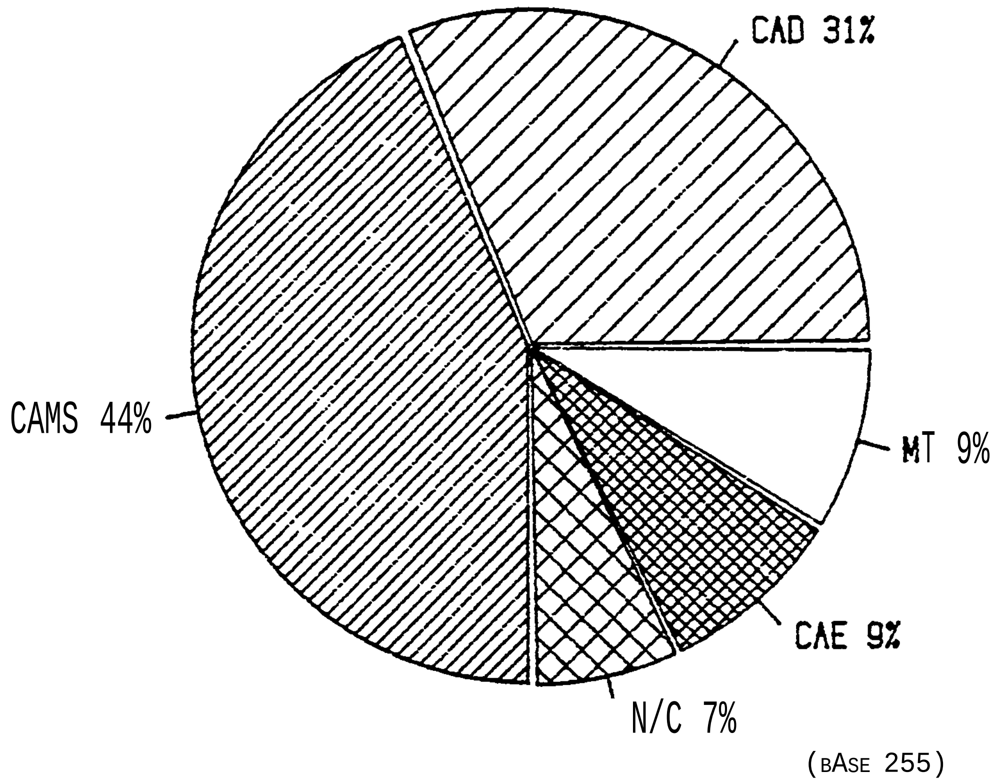

Figure 2. Shipyard Future Plans for CAD/CAM Technology by System Type

The CAD/CAM category with the most future implementations is computer assisted management systems at 44%. Most shipyards already have some degree of computer assisted management systems, so 44% represents expansion or replacement (with a system that has more coverage reach) of current systems. Computer aided design expects to receive 31% of new implementation. Five shipyards are planning or implementing totally new (first-time) CAD systems whereas 7 other shipyards are expanding or replacing their current CAD systems. Of those 7 expansions most are writing interfaces for their CAD system to increase its ability to tie into other activities such as engineering analysis and Computer Aided Engineering analysis. The emphasis for CAE implementations is split between design analysis and production engineering in the six shipyards indicating future plans. Seven shipyards are planning Manufacturing Technology (MT) implementations representing 9 percent of all future plans. Three are planning for the more novel MTs including process planning, time standard generation and/or group technology, while the other four mean to implement lofting and/or nesting. N/C Process Control plans to implement 7 percent of the new applications. Three shipyards will be adding N/C cutting, two in their sheet metal shop, one in forming and stockyard and treatment.

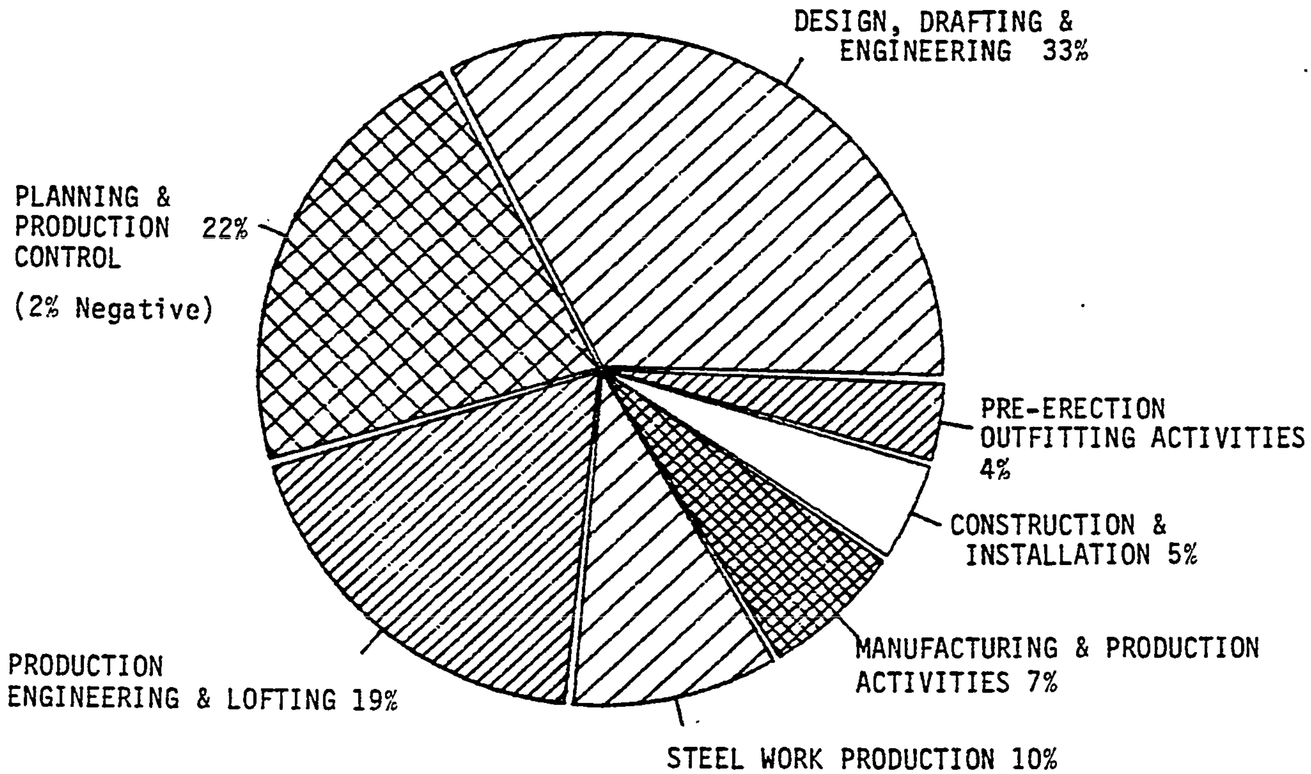

Figure 3. Shipyard Computer Technology Application by Functional Area

Design, Drafting, and Engineering contains the most computer systems application representing 33 percent of all shipyard CAD/CAM technology applications. It also is covered by five different CAD/CAM categories making it one of the more diversely covered shipyard functions. Most systems for the Design, Drafting, and Engineering category are vendor supplied. Planning and Production Control utilized 22 percent of the computer technology applications. These are almost exclusively management information systems which were developed in-house. Production Engineering and Lofting utilized 19 percent of the total CAD/CAM applications with a fairly even mix of the various types of CAD/CAM technologies. Lofting was the single most widely performed computer assisted activity on the survey. Steelwork production has a fairly even split between N/C and management systems and represents 10 percent of the total CAD/CAM use. Manufacturing and Production activities, Construction and Installation, and Pre-erection Outfit Planning are all covered primarily by management systems and represent minor utilization of CAD/CAM technologies (7 percent, 5 percents and 4 percent respectively).

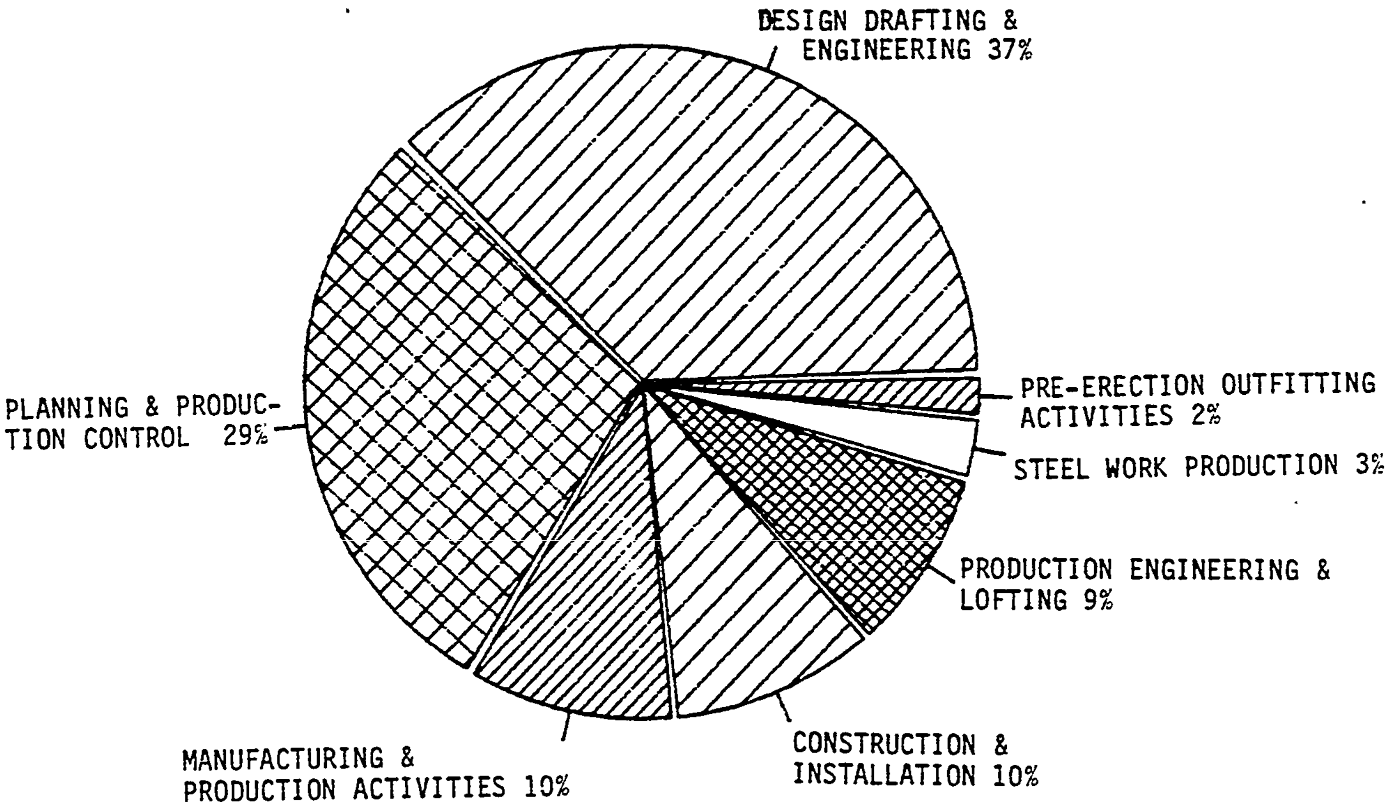

Figure 4. Shipyard Future CAD/CAM Applications by Functional Area

The distribution of planned future implementations is almost the same as the current applications by functional area (Figure 3). Design, Drafting, and Engineering is again planning to receive the largest number of implementations weighed heavily (67 percent) toward CAD systems expansion, modification and/or replacement. Some design related engineering is anticipated (22 percent) though other plans are neg1igiable. Planning and Production Control rate 29 percent of the surveyed future applications. There is no indication whether these will continue to be in-house developed (though the trend is in that direction) or if the shipyards will implement vendor packages, now that more are available (refer to SP-4 Software Tools Project). Construction and Installation activities are planning to implement 26 new applications (10 percent of total) 73 Percent of which are management information systems. Manufacturing and Production Control also plans for 10 percent of the applications with 46 percent management, 34 percent Manufacturing technology and 20 percent N/C process control systems. Steelwork has been fairly well computerized in the past but 3 percent of the future plans are in this area, primarily for upgrading to N/C equipment. Pre-erection Outfitting Activities have the lowest current application of CAD/CAM technology and will continue to be non-computerized for the near future, at least, with only 2 percent of the applications planned for it. These four applications are all management systems related.

Comparing the current and future production-oriented categories also reveals some important changes in emphasis. Steelwork production has apparently reached its saturation point, at least in the priorities for the next five years, since new implementations are only 3 percent compared with 10 percent of the current applications. Manufacturing and production activities, and construction and installation are given equal weight, 10 percent, in the planned future implementation and both represent relative improvements to their current contributions. In otherwords, in five years these categories should show relative increase in overall computerization compared to their current positions. Pre-erection outfitting activities show an even lower future trend than their currently low position even though this is an area that currently is receiving a lot of non-computer implementation currently, (based on observations during shipyard visits). This low emphasis is not necessarily a negative indicator, it may well simply imply that implementation of the techniques are too new to be effectively computerized in the next five years.

2.1.3 Overall Top Shipyard Application of CAD/CAM Technology

To more specifically analyze the nature of computerization the overall top ranking (more application across the six CAD/CAM technology areas) shipyard activities are listed in Table 3.

TABLE 3 OVERALL TOP CAD/CAM APPLICATIONS BY SHIPYARD FUNCTIONS

Current Applications (#)	Future Applications (#)
1. Lofting (26)	1. Mechanical/Structural Part Def (9)
Cutting (21)	2. Shop Drawing Generation (8)
2. Parts Nesting (19)	3. Piping Definition (8)
4. Mechanical/Structural Part Def. (19)	4. Clearances/Interferences (8)
5. Hull Form Def. and Analysis (18)	5. Sheet metal work (7)
6. Cutting Path Development (17)	6. Electrical Parts Definition (7)
7. Fabrication Detail Generation (16)	7. Pipework (7)
8. Hull Fairing (15)	8. Outfitting/Accommodations Def. (6)
Structural Analysis (14)	9. Parts Coding (6)
l0. Parts Listing (14)	

The current top applications show a few very logical trends. Lofting, hull fairing, hull form definition and structural analysis are all critical aspects of designing and producing a ship. They are also very step-wise, complex, mathematical problems making them good candidates for computerization. Cutting, nesting, cutting path development, and structural part definition are primarily functions applied to steel plate in the U.S. shipbuilding industry and are the production-oriented complement to hull definition, fairing and lofting. These capabilities began up to 15 years ago and have been building-up over the last 10 years. More recently, over the last five years, many U.S. shipyards have become involved with CAD/graphics systems primarily for drafting purposes. Mechanical/structural part definition and shop drawing generation are specific functions that drafting systems affects directly. Indirectly, fabrication detail generation and parts listing sometimes interface with drafting systems or run in parallel via management information systems. This leaves the category of other analysis. The other analysis activity involves the specific engineering analysis listed in the Computer Aided Engineering Analysis category (e.g., hydrostatic, hydrodynamic, heat transfer). These analyses are very mathematical methods and have been computerized for several years. Probably more software is available to these analyses than any other single surveyed function. Notice that all the current top applications come from Design, Drafting, and Engineering (Al) or Production Engineering (A2) categories (Appendix F), except cutting.

The top planned future implementations show some trend toward manufacturing-oriented applications. Though most trends are CAD technology related, in the Design and Drafting major functional area (i.e., 1,2,3,4,6,8,9), sheet metal work and pipe work are manufacturing shop oriented. Specifically sheet metal and pipework activities both show a trend toward N/C and manufacturing technology, with some management systems involvement. Whereas pipework has successfully utilized CAD/CAM technologies for several years (though a slow moving trend), sheetmetal work is a rather recent trend, which may be more quickly implemented. Meanwhile, design, draft and engineering related activities continue to show the strongest growth primarily due to expansion of the use of CAD drafting systems and improvements in CAD technology capabilities.

The largest trend observed outside of CAD/CAM or computerization seems to be the implementation of pre-erection outfit planning methods, particularly module/block construction. The second phase of this survey, shipyard visits, observed the beginnings of outfit planning at most shipyards. Though it is not directly affecting the computerization, current or future, at most shipyards (except shipyard K) it may be a part of the future plans five years away. In addition,” while many U.S. shipyards show module building capability, very few reflect a total change in shipbuilding philosophy. Areas observed that are not currently being addressed via outfit planning techniques include scheduling, warehousing, inventory control (palletizing, etc.), and/or procurement methods, except by a few shipyards. Thus, Outfit Planning has become more than just a buzz word, it is being implemented, but it has a long way to go if it is to be fully implemented at most facilities.

2.1.3.1 Shipyard Trends in the Design, Drafting and Engineering Functions

The actual distribution of CAD/CAM technology, present and future applications across the design, drafting and engineering functions is shown Figure 5. Eighty-six percent of the current design applications are contributed by CAD, CAE and N/C systems in a 3.4:2.4:1 ratio. Actual CAD and CAE technologies overlap in an unusual fashion. Vendor turnkey CAD systems (sometimes mistakenly proclaimed by vendors as CAD/CAM-systems) are used almost exclusively for drafting in the shipbuilding industry whereas some of the CAE and N/C software has graphics capability. The N/C and engineering aspects of the turnkey CAD drafting systems are virtually ignored (refer to section 3.4.3). Manufacturing technology is primarily referring to parts nesting and lofting capabilities, any other implications are obvious. Management systems have very little impact on design, drafting and engineering activities, 9 percent and usually refer to parts listing and material requirements planning as opposed to management and control of designers, draftspeople, and engineers. Considering the amount of computerization spent to schedule, plan and control direct labor (section 2.1.3.3) this seems disproportionately low. Planned future implementation follow the current trends very closely with somewhat less emphasis on systems other than CAD drafting systems.

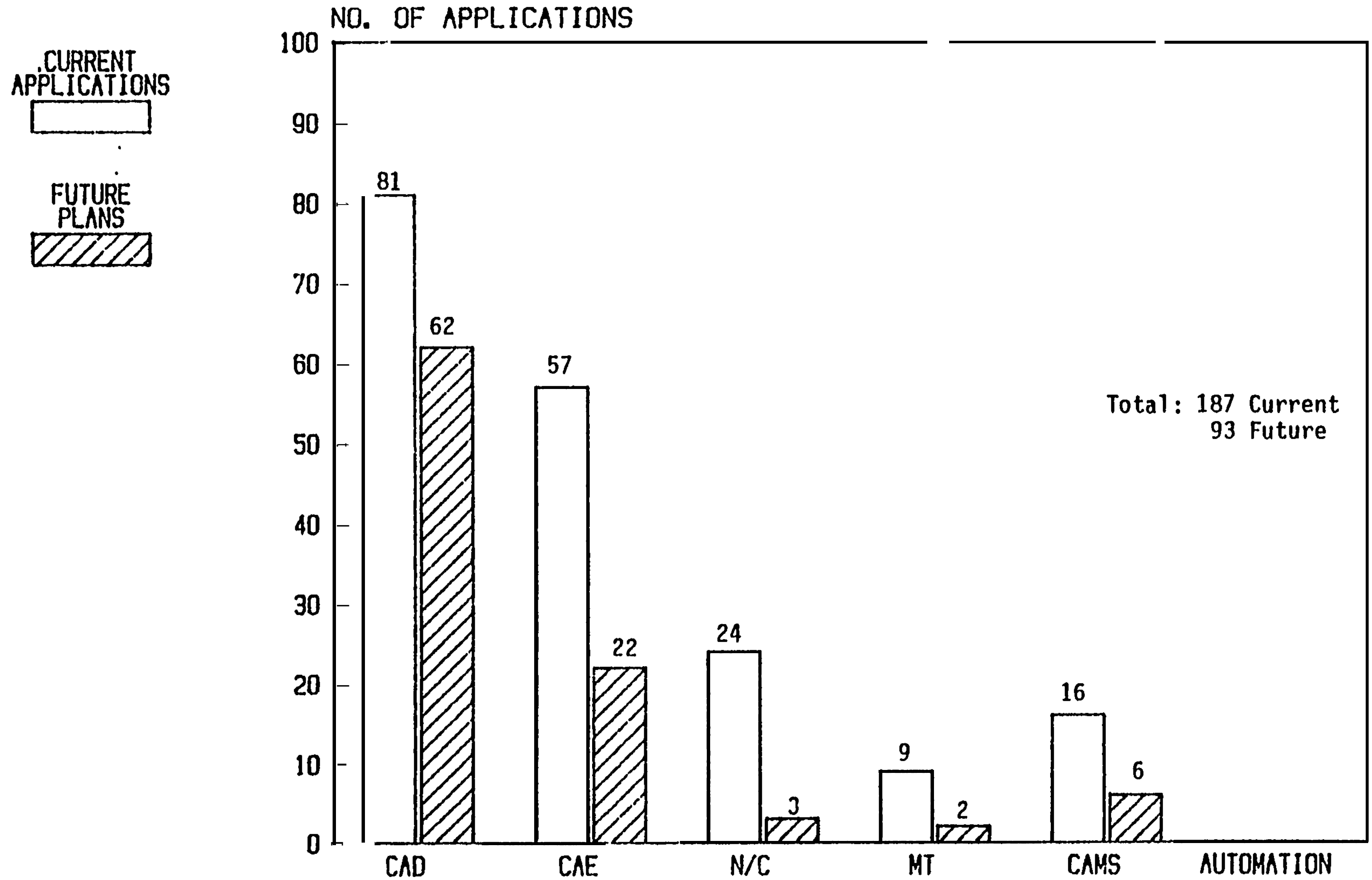

Figure 5. CAD/CAM Technology Applied to Design, Drafting and Engineering

Table 4. Design, Drafting and Engineering Top Applications (by function)

Current Applications (#)	Future Applications (#)
1. Mechanical/Structural (19)	1. Mechanical/Structural (9)
2. Hull Form Definition & Analysis (18)	2. Shop Drawing Generation (8)
3. Structural Analysis (14)	3. Piping (8)
4. Parts Listing	4. Clearances/Interfaces (8)
5. Shop Drawing Generation (14)	5. Electrical (7)
6. Geometric modeling (12)	6. Outfitting/Accommodations (6)
7. Other Analysis (12)	7. Parts Coding (6)
8. Area/Volume Analysis (11)	8. Hull Form Def. & Analysis (5)
9. Parts Definition (10)	9. Material Requirements Def. (5)
10. Outfitting/Accommodations (10)	10. Parts Listing (4)
	11. Area/Volume Analysis (4)
	12. Production Systems Eng. (4)

For a closer look at the specific application trends for design, drafting and engineering functions Table 4 identifies the top performers. The current applications ranked 1, 2 and 3 all involve structural definition and analysis. Both drafting systems and engineering-N/C systems (e.g. AUTOKON, SPADES) cover these applications, though seldom in an integrated or interfaced manner. Parts listing, 4, is applied as a part of CAD, N/C and management systems depending on the context of the listing; again seldom interfacing these together. Shop drawing generation, geometric modeling, parts definition and outfitting/accommodations (5, 6, 9, and 10, respectively) are all primarily functions of CAD drafting systems. Parts definition and geometric modeling, also have applications in the CAE, N/C, and manufacturing technology categories. In shipbuilding very few CAD drafting systems were used to generate N/C tapes or to perform nesting operations therefore, parts definition and geometric modeling, while activities in drafting systems, were primarily converted to production analysis and used via engineering-N/C systems. Area/volume and other analysis are primarily CAE category applications although some do involve CAD graphics.

The appearance of material requirement definition and production systems engineering on-the future applications list is significant because they have very few current implementations (3 and 2, respectively). This implies that these are important needs of many shipyards and may suggest a trend toward their computerization. Also, the plans for electrical and piping part definition are positive for similar reasoning, however they have more current implementation at 5 and 7, respectively. Clearance/interferences analysis is planned in anticipation of implementing upgraded CAD software which allows the user to define "soft" interferences and perform analysis to determine if anything violates defined spaces (e.g., walkways, machinery space).

2.1.3.2 Shipyard Trends in the 'Production Engineering and Lofting

The distribution of CAD/CAM technology applications used for both current and planned future production engineering activities is shown in Figure 6. Lofting and parts nesting are two of the most applied CAD/CAM capabilities (1 and 3 overall), Table 5, and provide most of the 24 applications for the manufacturing technology category. Usually these capabilities are a part of other systems such as CAD packages or CAE-N/C systems, which accounts for several of the application in these areas. Cutting path development and hull fairing are often in the same software program (e.g. AUTOKON, SPADES) and also add applications to the CAD, CAE, and N/C categories. Fabrication detail generation computerization is considered primarily N/C and CAD capability though there are a few instances were CAE and manufacturing technologies (such as parts nesting) apply. Dimensional and quality control is also considered primarily a function of N/C and CAD systems via their ability to perform diagnostics on cutter path and proper scaling/ dimensioning. Computerized process planning is a relatively recent development (last five years) which has not yet found application in most U.S. shipyards. Many of the first generation systems depended on heavily grouped technology or classification piece-part coding schemes primarily aimed at job shop operations. The value of extending these concepts to shipbuilding shop and construction/assembly activities is apparently difficult to determine, though at least two shipyards are moving in this direction. Pre-erection outfit planning techniques seem conducive to computerized process planning and therefore U.S. shipyards may implement it in the longer term.

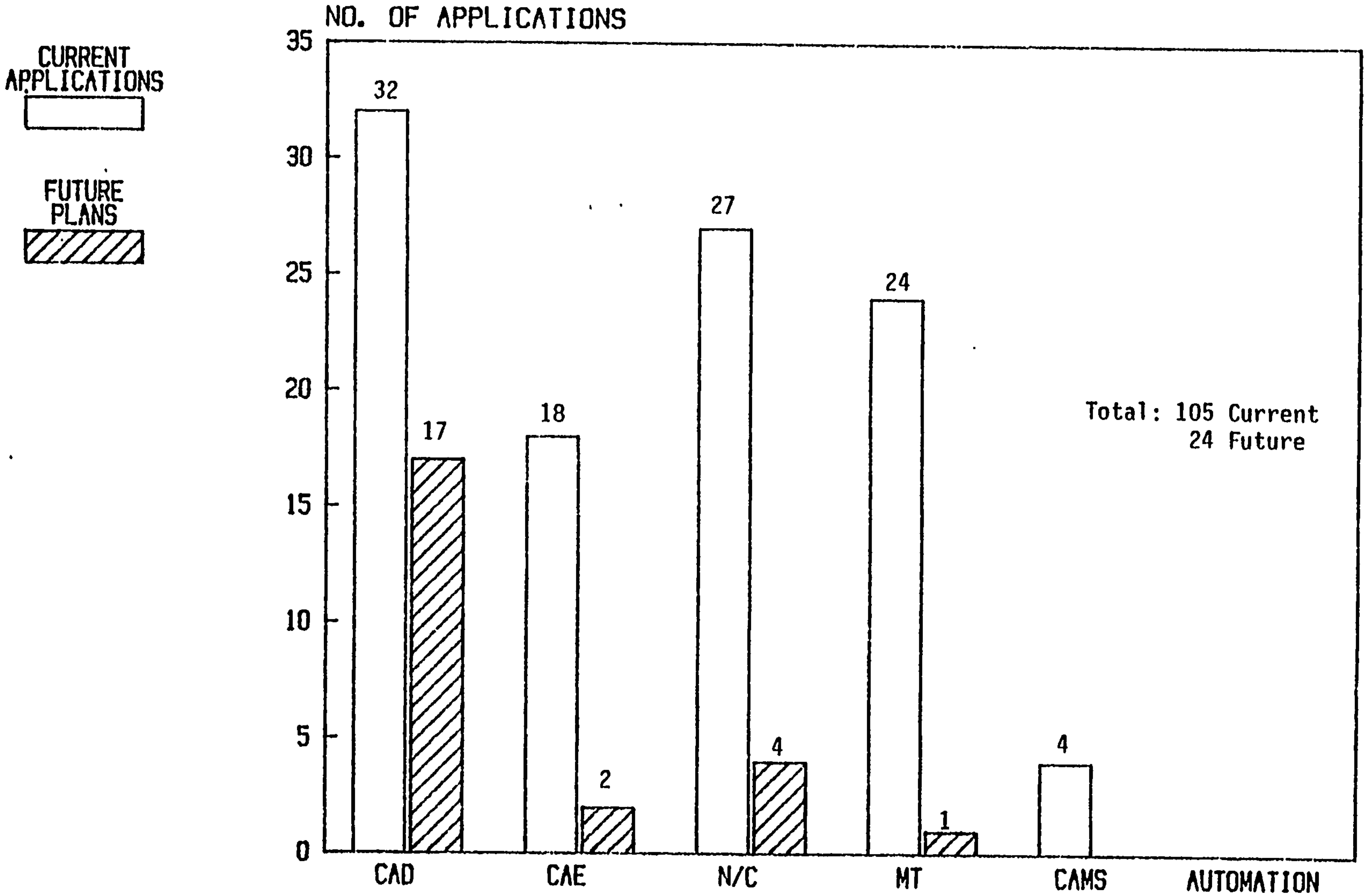

Figure 6. CAD/CAM Technologies Applied to Production Engineering and Lofting

TABLE 5. Production Engineering and Lofting Top Applications (by Function)

Current Applications (#)	Future Implementations (#)
1. Lofting (26)	1. Fabrication Detail Generation (4)
2. Parts Nesting (19)	2. Lofting (1)
3. Cutting Path Development (17)	3. Parts Nesting (1)
4. Fabrication Detail Generation (16)	4. Cutting Path Development (10)
5. Hull Fairing (15)	5. Hull Fairing (1)
6. Dimensional & Quality Control (10)	6. Dimensional & Quallity Control (1)
7. Process Engineering (1)	7. Process Engineering (1)

2.1.3.3 Shipyard Trends in the Planning. & Production Control Functions

As is shown in Figure 7, CAD/CAM Technologies applied to Planning and Production Control and practically all applications via management systems. Unique applications are sometimes more revealing than mass trends which make the four non-management applications of interest. Three of the manufacturing technology applications are diverse and unique. One application is in the quality control activity. Based on the repair yard's software the manufacturing technology, the link to quality comes from their in-house developed process planning program which they apply primarily to N/C shop activities. Another shipyard suggests that their nesting and lofting software provides the proper information to assist in steelwork production scheduling, while the final manufacturing technology user has their own in-house developed facilities planning program, which is used in conjunction with their CAD/graphics systems. All future plans for manufacturing technology applied to planning and production control belong to one shipyard and are to assist work organization, steelwork production and performance calculations. The manufacturing technologies that may accomplish this are process planning, time standard generation, and group technology. An automated materials handling system provides one shipyard with a very direct level of control and another shipbuilder plans to do the same in the near future.

A specific understanding of the major current and future implementations, Table 6, will assist in explaining management systems trends. Most current scheduling applications (5,6,8, and 9) serve more as post-scheduling systems since most work breakdown and milestone determination is decided via an experienced planner with no computer assistance. The computer then serves to

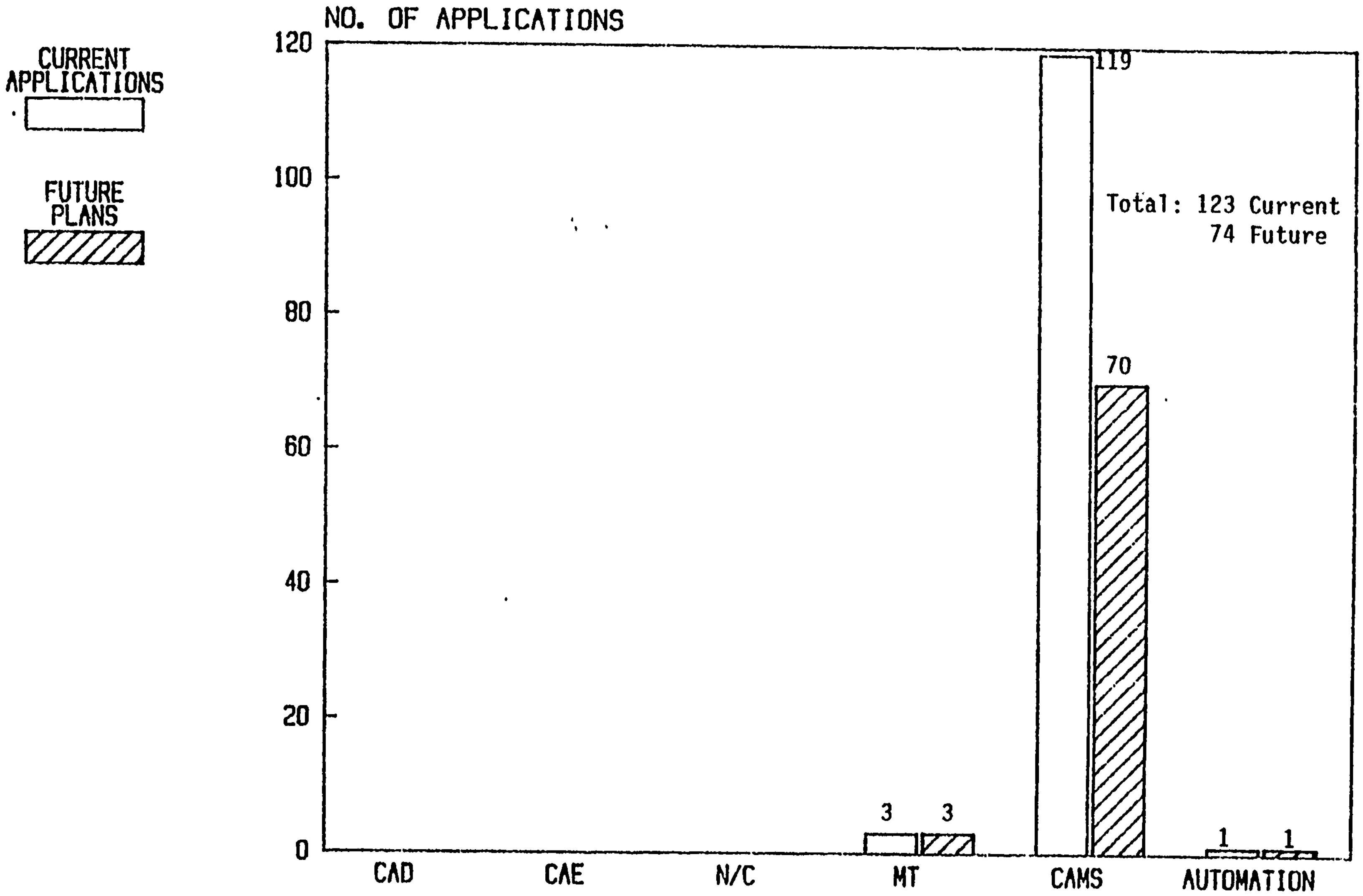

Figure 7. CAD/CAM Technologies Applied to Planning and Production Control

TABLE 6. Planning and Production Control Top Applications

Current Applications (#)	Future Implementations (#)
1. Inventory Control (11, 1 negative)	1. Purchasing (5)
2. Purchasing (10	2. Estimating (5)
3. Performance Calculations (10	3. Contract Scheduling (5)
4. Ship Construction Control (10, 1 neg.)	4. Steel Work Production Control (5)
5. Steelwork Production Scheduling (9,1 neg.)	5. Outfit Installation Control (5) Inventory Control (4)
6. Ship Construction Scheduling (9)	6. Steelwork Production Scheduling (4)
7. Estimating (8, 1 neg.)	8. Outfit Production Scheduling (4)
8. Outfit Production Scheduling (8, 1 neg.)	9. Work organization (4)
9. Contract Scheduling (8, 2 neg.)	10. Outfit Installation Scheduling (4)
10. Work Organization (7)	11. Outfit Production Control (4)
11. Quality Control(7)	12. Material Handling (4)

break down some work in more detail (e.g. some PERT type analysis) but primarily act as an information base against which performance calculations (1) and schedule control functions (4, 10, and 11) are determined. Although most systems do not actually initiate a schedule, they are becoming more sophisticated and less bookkeeping oriented. More systems are providing the ability to perform some limited sensitivity analysis for time, precedence and manpower utilization and some historical referencing. More importantly however, the control aspect of many shipyard scheduling systems is becoming more reliable and useful to the direct supervisory level of ship construction. Inventory control and purchasing systems are currently more bookkeeping oriented and have had a limited impact despite their number of applications. However, in at least two shipyards visited, a computerized materials catalog was provided standardization and continuity to their operations, which if developed to interface with other scheduling and drafting functions, could provide a very responsive system. Most inventory control application problems are simple ones of physical location and human factors. Unlike a job shop operation where all parts can be stored in a common area, shipyard's warehouses are usually dispersed throughout the construction site and people continue to circumvent inventory control procedures for rush jobs, etc. This results in inaccurate in ventories and part location problems.

Future plans show a positive trend toward purchasing and estimating applications. Since procurement can account for upwards of 60 percent of the cost of a ship, more computer assisted control in this area could result in large savings. Estimating systems in the past have been simplistic and of limited value. It is uncertain that the new applications will be arty better, however, the amount of activity in that area and the evolutionary nature of management systems is certainly a positive indicator. Four applications appear as future trends that are among the lowest current implementations. These are steelwork production control, outfit installation control, outfit production control and materials handling. This emphasis on control continues to close the loop and make management systems more responsive to actual ship construction factors.

2.1.3.4 Shipyard Trends in Steelwork Production

Steelwork production is the most mature function in the shipyard with a fairly even mix of N/C, manufacturing technology, management systems and automation (32 percent, 15 percent, 46 percent and 7 percent, respectively) as shown in Figure 8. In addition, many of the previous functions support steelwork via lofting, hull fairing, and N/C tape preparation. Next to lofting, cutting is the most widely computerized activity, overall, and by far the major application in the steelwork activity, refer to Table 7. Forming via line heating and bending and outfit steelwork are the other emphasis in the steelwork function. The future holds no surprises as more shipyards upgrade old manual cutting and bending equipment with N/C.

TA8LE 7. Steelwork Production Top Applications

Current Applications (#)	Future Implementations (#)
1. Cutting (21)	1. Cutting (4)
2. Forming (10)	2. Forming (2)
3. Outfit Steelwork (7)	3. Stockyad & Treatment (2)
4. Stockyard & Treatment (5)	

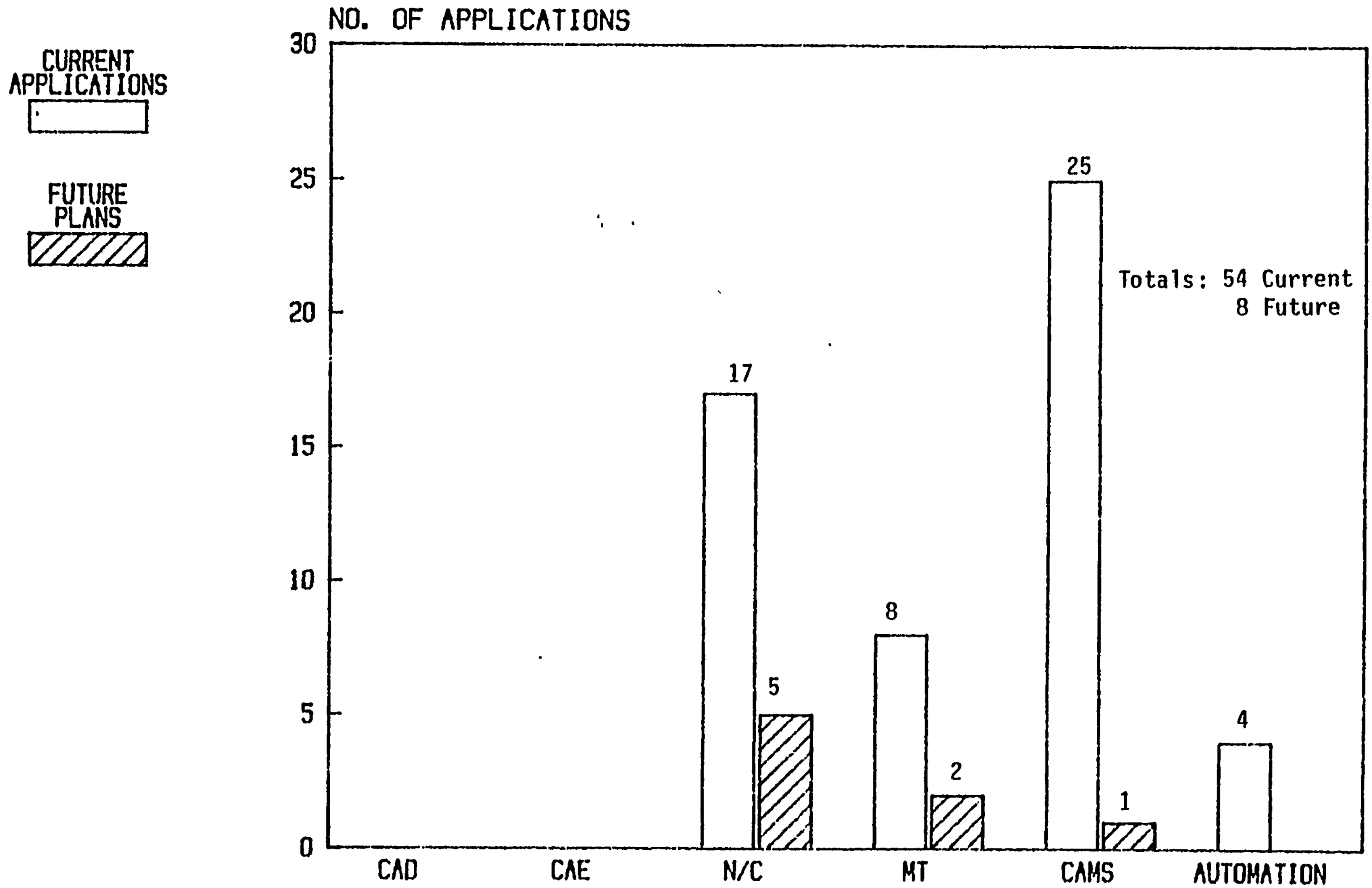

Figure 8. CAD/CAM Technologies Applied to Steelwork Production

2.1.3.5 Shipyard Trends in Manufacturing and Production Activities Functions

As the amount of direct manufacturing activities increases computerization decreases. Four of 18 shipyards are applying N/C to their production shop activities resulting in nine applications, Figure 9. These applications covered primarily the machine, sheet metal and pipe shops. Future plans for N/C were evenly split between sheet metal and the machine shop and there is one pipework application expected. Manufacturing technology is applied by two shipyards, one for sheetmetal and the other for the blacksmith shop. Future plans at one shipyard account for eight of the nine manufacturing technology applications, which may suggest computerized process planning or time standard function. Nine shipyards' management systems result in 27 applications in the production shop activities leaving four shipyards without direct coverage of these applications by their systems (and five more without management systems at all). Two of the four plan to apply computer assisted management systems to these areas in the future accounting for all but one of the 13. The exact nature of the one automation application for sheetmetal work is not known, it is possible that it is a robotics application (refer to Shipyard o, Appendix c).

TABLE 8. Manufacturing and Production Activities Top Applications

Current Applications (#)	Future Implementation (#)
1. Sheetmetal Work (10)	1. Sheetmetal work (7)
2. Warehousing (9, 1 negative)	2. Pipework (7)
3. Engineering/Machine Shop (5)	3. Elect rical (5)
4. Pipework (5)	

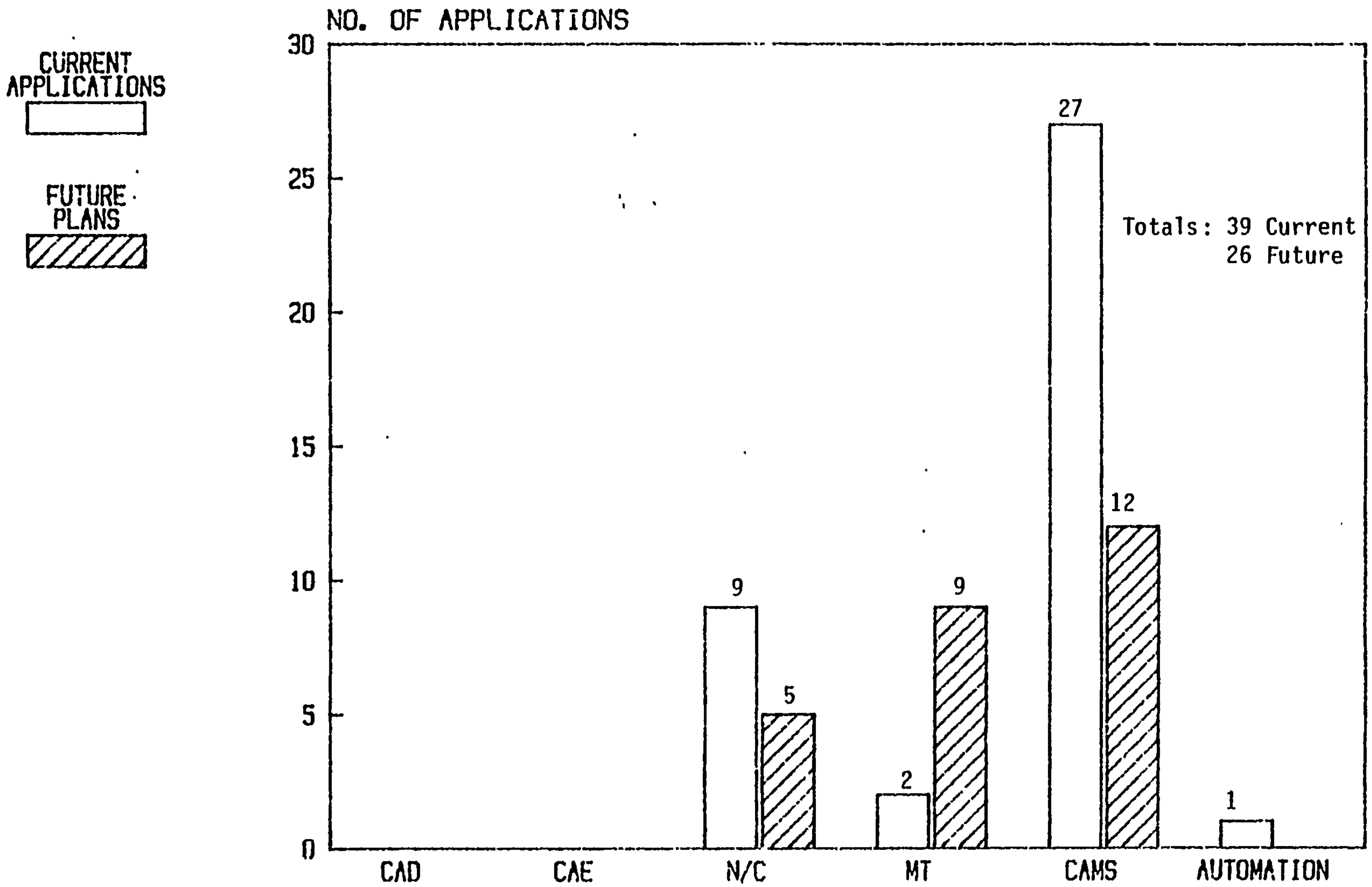

Figure 9. CAD/CAM Technologies Applied to Manufacturing and Production Activities

2.1.3.6 Shipyard Trends in the Pre-Erection Outfitting Activities Functions

This area, as mentioned earlier, is currently being implemented into the organizational structure at many shipyards and there is not a clear enough view of what affect pre-erection outfit planning will have to computerize it at this time. The exception are six shipyards that feel that their management system covers these applications and two others that intend to adjust theirs to do so. An exemplary system is reviewed for Shipyard K in Appendix C. Its system and organizational structure has very recently been totally adjusted toward the outfit planning method of ship construction. Future computerization plans in this area should be the norm five years from now, based on shipyard visit observations.

2.1.3.7 Shipyard Trends in the Construction and Installation Functions

Management systems are the dominant CAD/CAM technology application area in ship construction and installation activities. In fact, the distribution, Figure 11, is almost the same as for pre-erection outfitting activities, but for different reasons. Pre-erection outfitting had a low application rate because it is a relatively new method being implemented at U.S. shipyards. Construction and installation have very few applications (five shipyards with 26 applications via management systems) because their computer assisted management systems are just reaching the level of sophistication where they can be useful to the direct supervision. Therefore, the “low showing” can still be taken as a positive trend and there is a reasonable level of future plans from three other shipyards to further support this interpretation. Several shipyards visited indicated that their first line supervisors (foreman level) were becoming more involved with the computer for managing daily operations. Automation is applied to welding via robotics and testing via sea trail simulation(s). Possibly the reason there are no future plans is that, so far, robotics has not proven itself in the cost analysis. Manufacturing technology is contributing to welding with future plans in welding, staging and access, pipework, engine room machinery, hull engineering and testing, most likely via process planning and time standards.

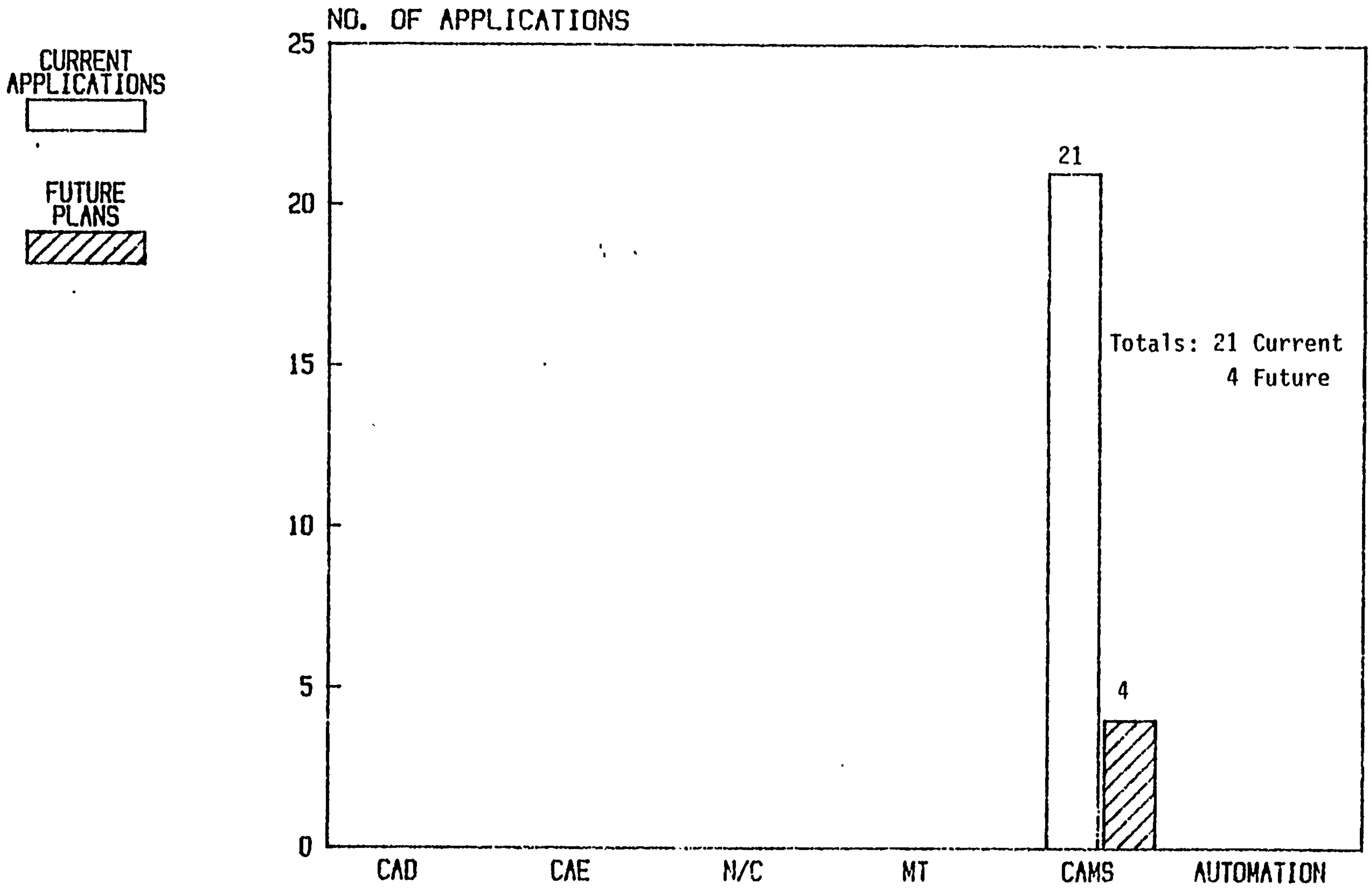

Figure 10. CAD/CAM Technologies Applied to Pre-Erection Outfitting Activities

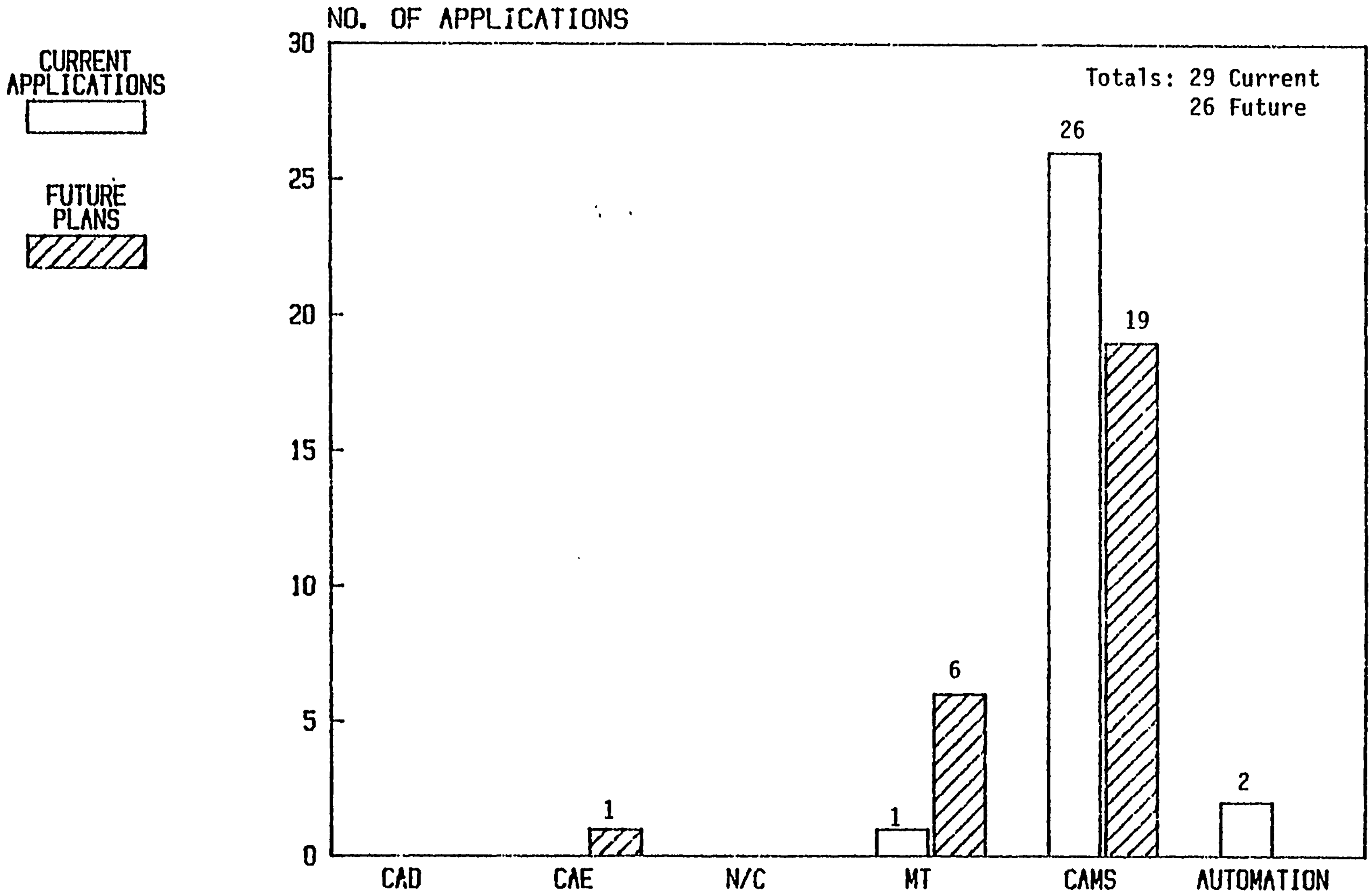

Figure 11. CAD/CAM Technologies Applied to Construction and Installation

2.2 DESIGN AGENCY RELATIVE TREND ANALYSIS

2.2.1 Introduction to Design Agent Analysis

Design agencies are broken out separately due to their different, yet overlapping, functional emphasis relative to shipyards/builders. A design agent's end product is a conceptual and/or preliminary ship design, as well as other engineering and design support services they may offer, which provides a heavy design emphasis. By contrast, the production engineering, planning and actual construction of a shipyard provide a ship production emphasis. Though some shipyards have conceptual and preliminary design capabilities (overlapping capabilities) a separate analysis for design agencies provides a clear review of their CAD/CAM technology use, aids in analyzing shipyard trends (by not biasing them), and provides recognition to an established shipbuilding service, which is, for the most part, an integral part of the U.S. marine construction industry.

The difference in corporate function also provides a different potential for the use and integration of CAD/CAM technologies within a design agency's facility. For this survey a design agency's potential for CAD/CAM use extends from design through production planning (refer to Appendix E, Design Agency Potential for CAD/CAM Technology) but does not involve the actual direct erection/construction capabilities expected from a shipyard.

2.2.2 Design Agency Trends

As expected, the design agency trends for use of CAD/CAM technologies are heavy in engineering analysis and drafting (Figure 12) almost totally in the design, drafting, and engineering function (Figure 13). A majority of their top applications, Table 9, come from CAD drafting systems providing overall parts definition (current applications 1, 2, and 7) and geometric modeling. The other trends in their top applications are engineering analysis applications (3, 5, 6, and 8), with a greater emphasis on mathematical modeling than all 18 shipyards combined, and contract scheduling, which is the only application having many applications in the computer assisted management systems CAD/CAM category.

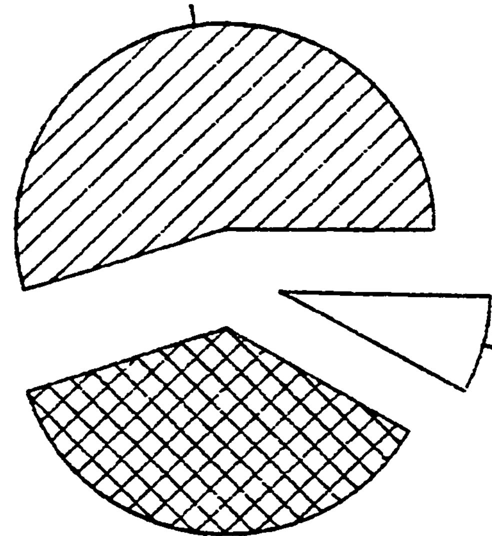

Figure 12. Design Agency Computer Technology Applications by Systems Type.

The primary use of CAD/CAM technologies is computer aided engineering analysis, 55 percent of all computerization (other than accounting), checking for conceptual design integrity and preliminary design accuracy. Three design agencies have implemented drafting systems over the last three years and the fourth served has future plans to do so. All CAD, including interactive graphics and hull definition and drafting applications account for 37 percent of computer technology usage. Computer Assisted Management Systems have five total implementations, at three design agencies, for a contribution of 8 percent of the CAD/CAM use. There are future plans for N/C process control at one design agency and two plan to add some manufacturing technology capabilities through parts nesting and process planning programs.

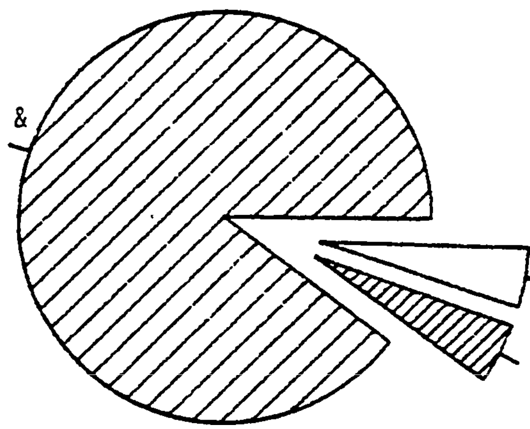

Figure 13. Design Agent Computer Technology Applications by Functional Area

Most of design agency CAD/CAM technology use by definition us in the design, drafting and engineering function. The survey found no exception to that with 90 percent of all applications in this category. Two production engineering applications come from one design agent's use of SPADES for hull fairing and the other application comes from a dimensional and quality control via an in-house program at another design agency. One design agent has two management systems applications, covering specification sheet generation and contract scheduling, with three future implementations planned including parts coding and listing and lofting (informational aspects to send to shipyards). Another design agent has contract scheduling computerized and a third design agency has two new implementations similar to the first design agent only with no further plans.

TABLE . Overall Design Agency Top CAD/CAM Functional Applications

Current Applications (#)	Planned Future Implementations (#)
1. Mechanical/Structural Parts Definition (6)	1. Mechanical/Structural Parts Def. (3)
2. Piping Parts Definition (6)	2. Parts Nesting (3)
3. Structural Analysis (5)	3. Lofting (3)
4. Geometric Modeling (5)	4. Geometric Modeling (4)
5. Mathematical Modeling (4)	5. Parts Coding (2) Parts Listing (2)
6. Other Analysis (4)	
7. Electrical Parts Definition (4)	7. Clearances/Interferences Analysis (2)
8. Area/Volume Analysis (4)	8. Fabrication Detail Generation (2)
9. Contract Scheduling (4)	9. Cutting Path Development (2)

Twoo of the design agencies use AUTO-TROL, a 2-D and/or 3-D system, and another uses CADAM with plans to acquire a 3-D solids modeling system and interface it to CADAM. The latter user also uses SPADES in conjunction with (though not interfaced to) CADAM and HULDEF. One of the former users applies NAVSEA programs for hull definition and fairing with no apparent interface to AUTO-TROL.

Future Trends, Figures 14 and 15, are primarily expanding CAD drafting systems applications to the design, drafting and engineering functions/ services for the design agencies. However, also implied is that most of the other future implementations (CAE, MT, N/C, and management systems) are in the production engineering and lofting functions of the planned future implementations. Parts nesting, lofting, and cutting path development (2, 3 and 9 respectively, Table 9) will expand a few design agents ability to provide more construction/production information to their clients. Similarly on the management information systems side, parts coding, listing, and fabrication detail generation will improve the usefulness of the design agent to their shipyard clients. Mechanical/structural parts definition, shop drawing generation, and clearance/interference checking will improve the quality of the design agent's products more than expand their capabilities. However, with the advent of IGES it may become necessary for design agents to do their work

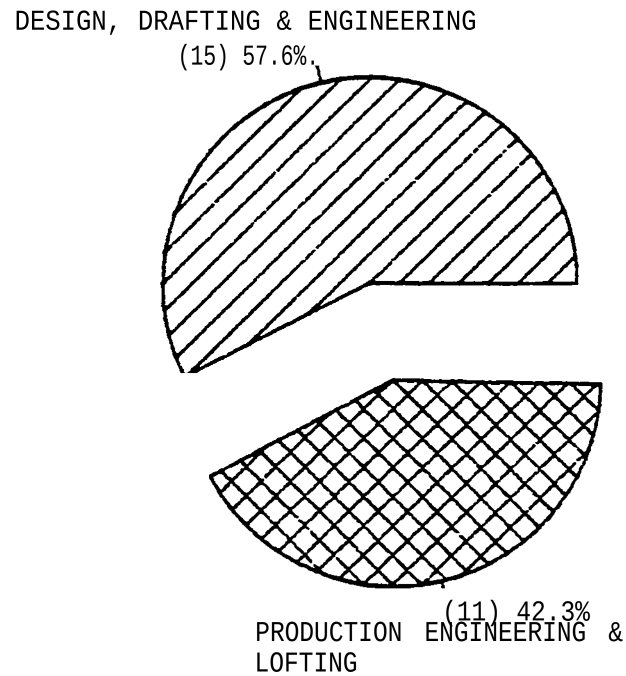

Fig. 14. Planned Future Design Agency CAD/CAM Technology by Functional Area

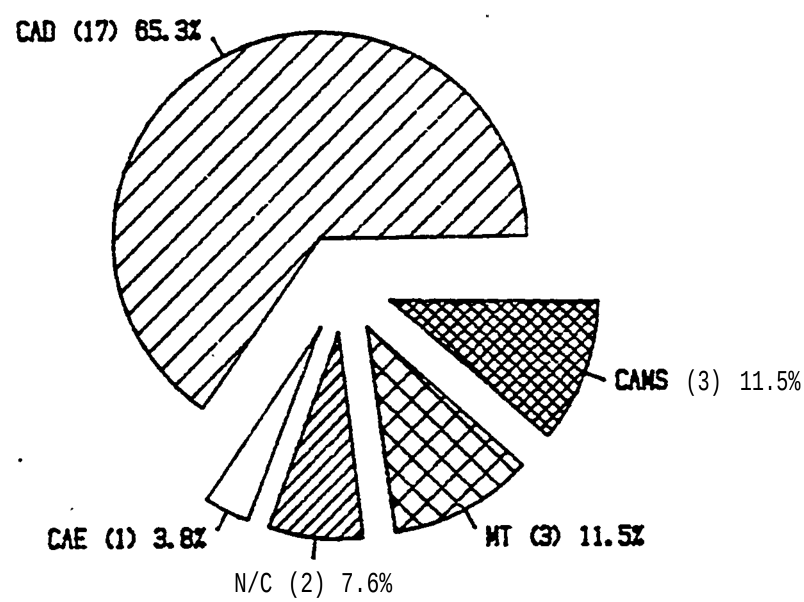

Figure 15. Planned Future Design Agency CAD/CAM Technology by System Type

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on a CAD drafting system, thus saving one major repetitive step: taking design agent's preliminary design drawings and recreating them on a shipyard's own system for the detailed design phases.

One final observation regarding solids and 3-D modeling: these new systems may be more readily useful to design agencies, especially in the area of conceptual design. Since these systems currently are not draftsperson user friendly (because they use non-drafting jargon and 3-D techniques) they may fit best with the people who are used to working in 3-D, namely, the conceptual modelers and physical model making personnel, then via IGES or some other interface converted to 2-D for drafting purposes. However, design agents have been using CAD drafting systems for a shorter period of time than most shipyards. The question becomes, with less experience in. the CAD field, are design agencies the one's who should be expected to lead the way in solids/3-D types of conceptual modeling?

2.3 ABSOLUTE TRENDS IN CAD/CAM

In this section trends are analyzed by absolutes as opposed to relative emphasis. The trends established in the previous sections are determined by reviewing the emphasis each CAD/CAM technology and functional area has received relative to the others. It is informative to understand relative trends but the analysis is incomplete without reviewing how each shipyard/ /design agency combines these technologies within their operations. This is done for shipyards in section 2.3.2, overall shipyard trends in number of applications, and in section 2.3.4 for design agencies. Once total company trends are established the next task is to analyze each major CAD/CAM system type not only by each shipbuilders number of applications but also by their own evaluation of the technology's success.

2.3.1 The Total Absolute Potential for CAD/CAM in Shipyards and Design Agencies

It is commonly understood that the totally automated factory (for manufacturing) is achievable with today's technology though currently not economical nor desirable to automate/computerize every function or even most functions within a factory or a shipyard. Determining the total potential to do so, however, provides a yardstick by which automation/computerization progress can be measured. The very fact that total automation could be achieved makes it important to find out just how much is being accomplished to date. Therefore, the total potential application is determined by review of the completed survey questionnaires, shipyard visits, and the research teams acumen in state-of-the-art CAD/CAM technology applications.

Appendices D and E, contains the shipyard and the design agents total current potential for CAD/CAM technology use across their respective functional breakdowns (or work breakdown structure) based on Part I of the CAD/CAM survey questionnaire. A shipyard has 244 potential CAD/CAM technology applications across 79 functional areas. To date, all 18 shipyards collectively have averaged 13 percent of their total potential CAD/CAM technology applications with a range of O percent to 27 percent. A design agency has 110 potential applications over their 31 functional areas. The four surveyed design agencies averaged 14 percent of their potential with a range of 3.5 percent to 22 percent.

The next logical questions are: what does this mean, is this a good or bad showing? These are not readily answered by the above mentioned statistics alone. Since there has been no measure of this kind in the shipbuilding industry before, it cannot be compared as growth or decline to any previous period; however, it provides an important vehicle with which to do so in the future. Also, there is no methodical way to compare this performance to the manufacturing or construction industry in general since they have not participated in a similar study. Therefore the judgment of the research team must suffice until future surveys provide more of a statistical comparison tool. Judgment dictates that 13 percent of potential is a better average than the overall manufacturing community would have (but lower than the Fortune 500 companies' average would be), which is similar to most defense industries and definitely higher than the construction industry. Observation suggests that shipyards, and to some extent design agencies, are at the end of a "wait-and-see" attitude toward computerization and are about to embark on a more certain, systematic, and accelerated approach in the near future. In other words, in five years the CAD/CAM survey should show a significant growth in number of applications and more integration/interface of systems (refer to section 3.5 for integration discussion).

2.3.2 Absolute Trends in Shipyards

In this section systems application by shipyard, Figure 16, and Functional Applications by Shipyard, Figure 17, are analyzed. As in the relative trend analysis two prespectives are useful: review by major CAD/CAM technology area and by major functional areas. Unlike the relative trend analysis, each shipyard is traced through its' individual mix of applications by area. In this sense absolute analysis has a micro-trend view (individual shipyard) whereas relative analysis has a macro-trend view (composite shipyard trends). The micro-trend view is also elaborated for some companies in the shipyard visit summaries, Appendix C. Also, to "facilitate absolute trend analysis Figures 16 and 17 have consistent symbols, each representing a specific shipyard.

2.3.2.1 Shipyard CAD/CAM Systems Trends

In general, shipyards fit into levels of systems application. The graph in Figure 16 shows that those shipyards strong in one technology are strong in others also, with few exceptions. N/C and CAD drafting systems are both established via turnkey systems in many instances and most that are strong in N/C or also strong in CAD. Potentially, the most significant trend is in computer assisted management systems. The top four performers in management systems rank 1, 3, 4, and 5 in overall CAD/CAM technology applications. The efficacy of management systems may well be the measure of shipyard sophistication and the number of management systems applications is a rough measure of efficacy. In support of this concept A. T. Kearney, Inc. surveyed 40 Fortune 500 companies and found that those with strategic planning and Information Resource Management (IRM) systems out performed the others by 300 percent based on average return on equity, return on profits, and new profit margin. The thesis is that to be in control is the most desirable condition (e.g., via strategic planning and computer assist management systems) and once this is achieved enhancement and or productivity improvements can be affected in a systematic and measurable manner. Automation does not have a large impact on the shipyard, currently, nor is it predicted to in the next five year's. Those shipyards experimenting in these areas today may well be the leaders once technoeconomic feasibility is established. Note that the top two implereenters of automation are among the top four in management systems.

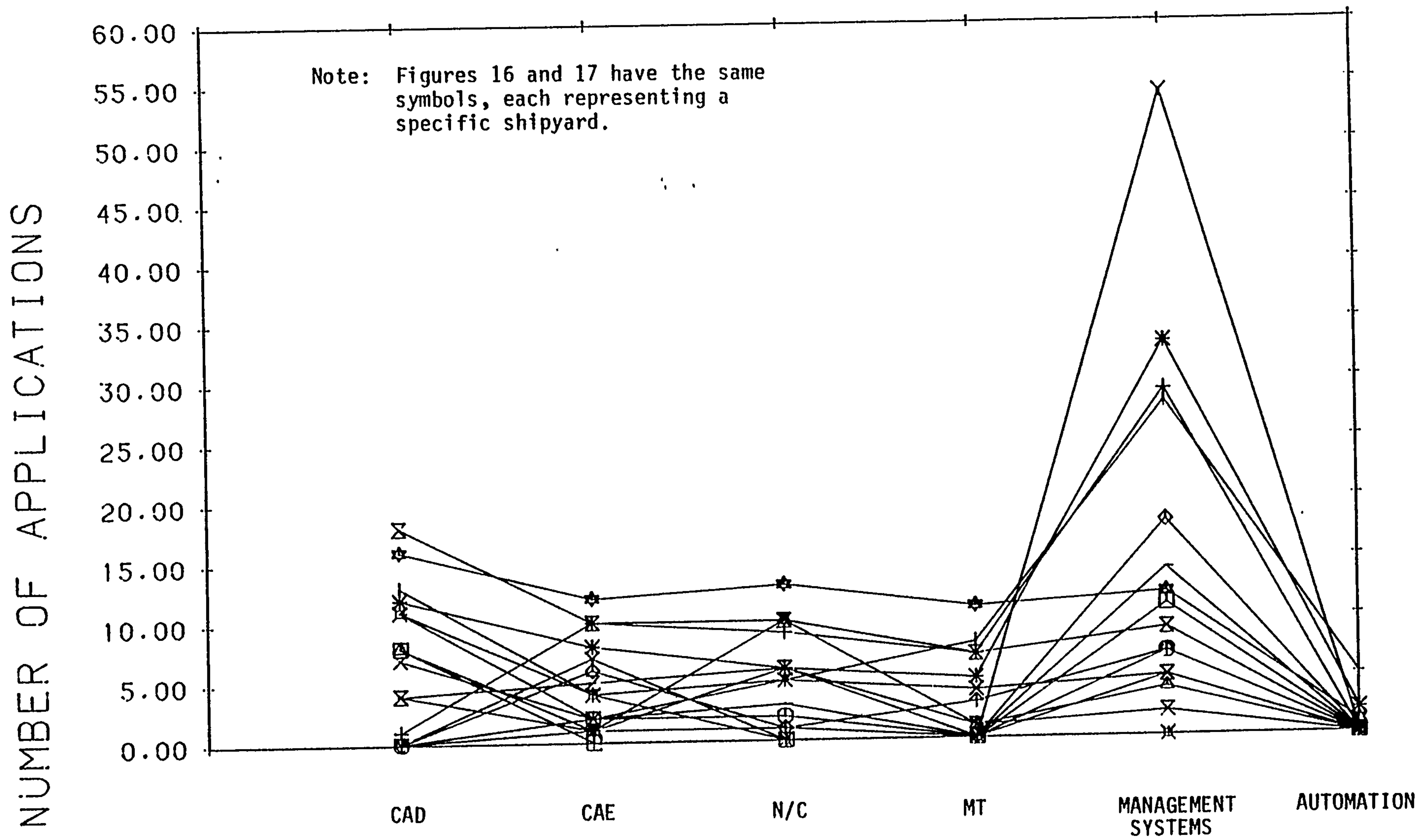

Figure 16. Systems Applications by Shipyard

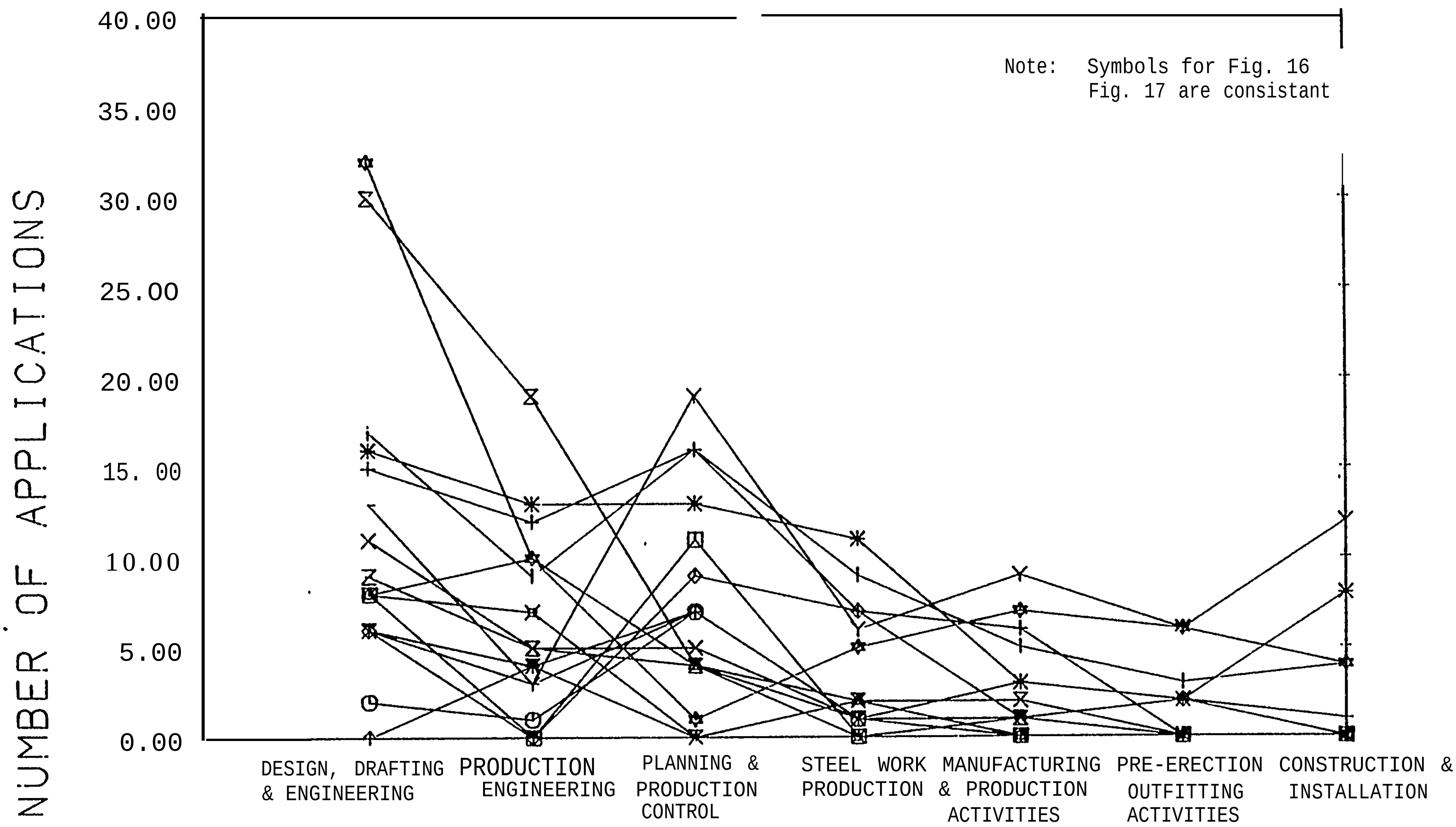

Figure 17. Functional Applications by Shipyard

2.3.2.2 Shipyard Functional Trends

Shipyards are quite varied in the manner in which they cover major functional areas via CAD/CAM technologies, as opposed to the clear levels shown by systems application. Computerization tends to decrease as actual production/erection activities increase or, in other words, computerization decreases as the level of planning decreases (Figure 17). The latter view tends to suggest that computers are used primarily for planning functions, this may be true in a product engineering sense but it is not true in the management information sense. Few management systems are used for the initial estimating for schedules, budgets, and manpower (Section 3.4.4) though some shipyards are improving in this respect. The top two performers in design, drafting, and engineering ranked 2nd and 6th overall and are the only top performers with a low number of management systems (Figure 16) or planning and production control (Figure 17) applications. Most of the applications representing manufacturing, pre-erection and erection activities are from management systems (refer to section 2.1.3.5-7).

2.3.3 Shipyard Evaluation of Systems Applications

The CAD/CAM survey questionnaire requested that respondents perform a simple evaluation of each application as they filled out Part I Matrix (Appendix F).

These are:

+ - Successful Application (2)
√ - **Satisfactory Application (1.5)**
- - Unsatisfactory Application (0.5)
N - New Application (1)

To quantify this for analysis purposes each symbol is given the value next to it in parentheses (above). In other words, shipyards have 244 applications maximum meaning that if all were successful applications (+) there are 488 total evaluation points possible. The purpose of this simple conversion is to analyze how successfully applications are evaluated. In fact negative applications do exist, primarily in management systems (refer to Figure 1), therefore a computer application can not always be regarded as beneficial.

Since the average number of applications is 31 or 13 percent of potential applications, per shipyard, a perfect showing for these would yield 62 evaluation points average or 13 percent of potential points. Instead it is slightly below this with 53 or 11 percent of potential. Overall, Figure 18, shows that only four shipyards fall below the satisfactory curve (1.5 times the number of applications) and these have a relative low number of applications. Notice, also that there is a definite split beginning with the evaluation curve at Shipyard #13 which sets six shipyards a large margin above the rest. This upper third also shows a greater degree of "successfulness" (qualitatively) than most of the others. This may suggest that 50 CAD/CAM applications is the first plateau from which greater returns are expected. Note this does not imply a break-even point since another six shipyards below the plateau are reporting satisfactory results; it may only imply a point of synergy where in-house capabilities/experience are farther down the learning curve. It is not appropriate to identify the top six CAD/CAM technology users and, the reader should be warned they are not necessarily the expected shipyards.

A closer review of the shipyard evaluations of each CAD/CAM system will add more insight into the total perspective of Figure 18. Shipyard CAD/CAM Evaluation. Each figure (figures 19-24) is listed in order of ascending number of applications and can be traced back to Figure 16, Systems Application by Shipyard, if desired. Note that new applications are **given** a value of one because they are not yet proven effective, thus they can prove to be satisfactory (1.5) or successful (2) or unsatisfactory (.5). The norm is considered to be satisfactory and therefore each graph, Figures 19-24, has a "satisfactory curve" (dashed line) for reference purposes.

2.3.3.1 Shipyard CAD Evaluation (Figure 19)

Two-thirds of the shipyards surveyed have computer aided design (CAD) applications either through CAD drafting, engineering, N/C and/or hull definition systems. More than half of the shipyards using CAD find it more than satisfactory and only two are less than satisfied with their current systems past performance. There are 16 new applications, one unsatisfactory, and an even mix of satisfactory and successful ratings (44 and 52 respectively). Overall, shipyards awarded 10 (19 percent) of the total evaluation points (25 percent of potential CAD applications) with the highest single rating at 2.85 (65 percent) of potential (67 percent of apllications).

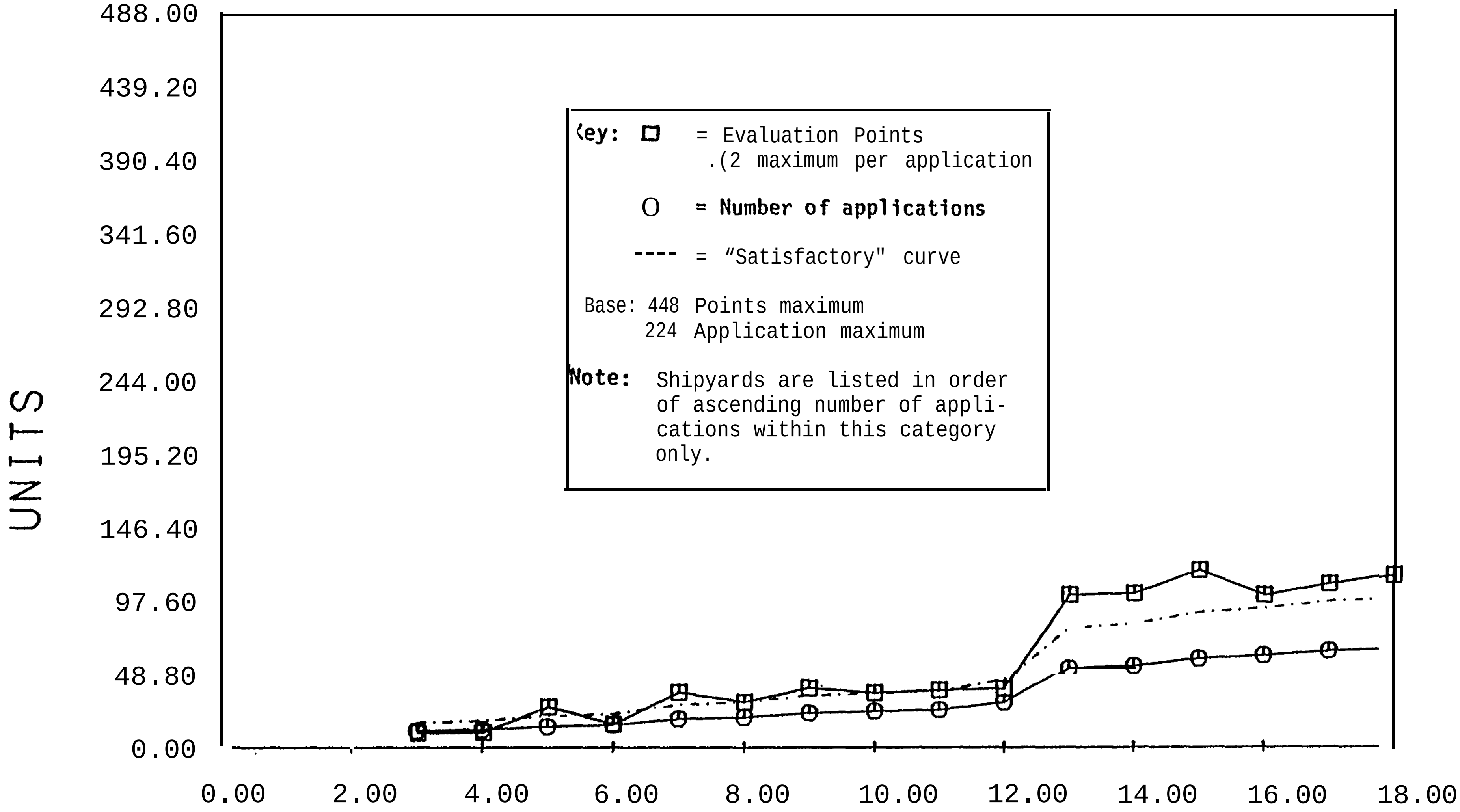

Figure 18. Shlpyard CAD/CAM Evaluation

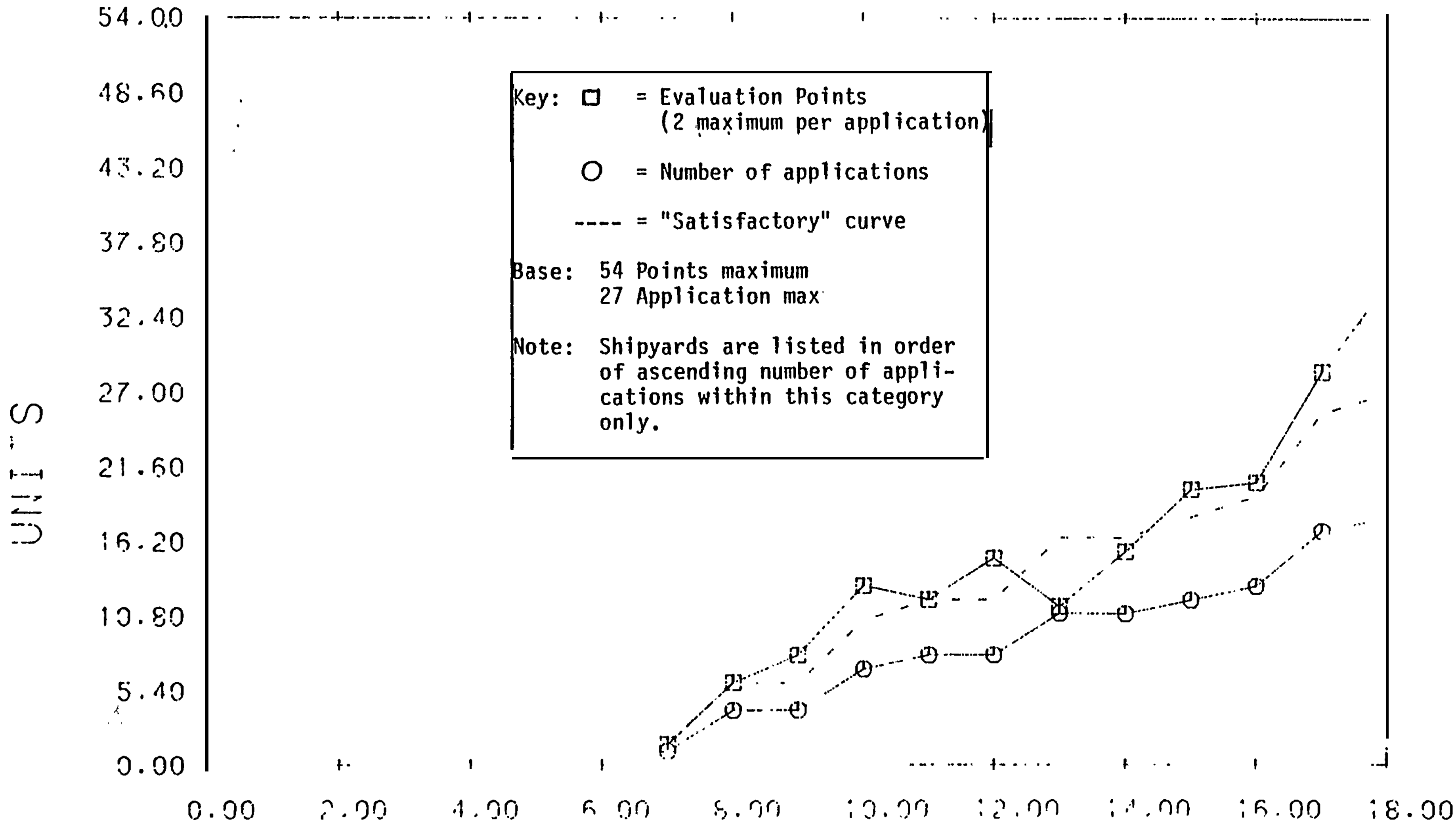

Figure 19. Shipyard CAD/CAM Evaluation

2.3.3.2 Shipyard CAE Evaluation (Figure 20)

The computer aided engineering (CAE) analysis systems area had four shipyards below the satisfactory curve all due to eight new applications, otherwise success (39 applications) and satisfactory (28) were the norm. Most CAE software is proven (refer to section 3.4.1) and therefore accounts for a strong showing. Once again the top users are showing higher opinion of using CAD/CAM technology. Overall, shipyards rated CAE 7 (14 percent) evaluation points (compared to 16 percent of applications) and maximum range extended out to a 23 (44 percent) evaluation (compared to 46 percent of applications).

2.3.3.3 Shipyard N/C Process Control Evaluation (Figure 21)

Numerical control technology is probably the oldest computerized manufacturing tool available and has no rating less than satisfactory. However, it also has no new applications. Fortunately, 18 more applications are planned for future implementation in the near future, including applications in pipework and sheet metal work. As the trend continues, marginal users observed marginal success. N/C is evaluated at an 8 point (10%) average (11% in application potential) with the maximum range at 26 (34 percent) evaluation points 13 (34 percent applications).

2.3.3.4 Shipyard Manufacturing Technology Evaluation (Figure 22)

Most of the manufacturing technology applications are attributable to parts nesting and lofting, however some applications included time standard generation and process planning. All of the eight identifying manufacturing technology applications averaged more than a satisfactory rating (33 pluses, 13 checks and one new application). Shipyards average 5 (4 percent) of the possible points (4 percent applications) and a maximum of 19.5 (16 percent) of the potential points and 18 percent of the possible applications.

2.3.3.5 Shipyard Management Systems Evaluation (Figure 23)

Computer assisted management systems have the most applications of any other, by a factor. of more than 2. It also has one of the most varied evaluations accounting for 12 unsatisfactory applications. However, there are only three shipyards actually averaging less than satisfactory. Number 8 on the graph is the least satisfied, rating themselves even worse than their number of applications (less than 1 on a scale of 2). The top four users in this category are among the top five total CAD/CAM technology implementers, and

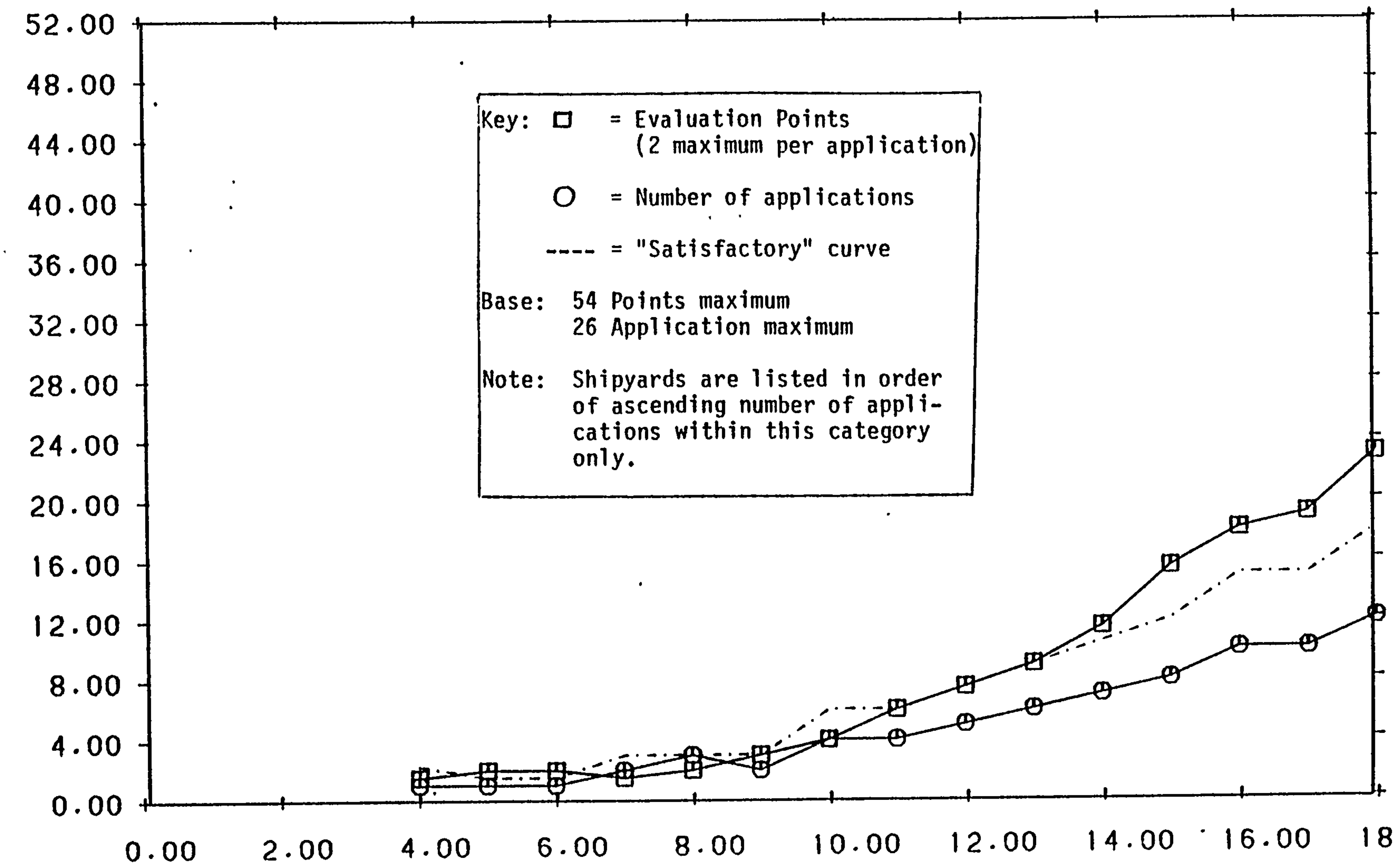

Figure 20. Shipyard CAE Evaluation

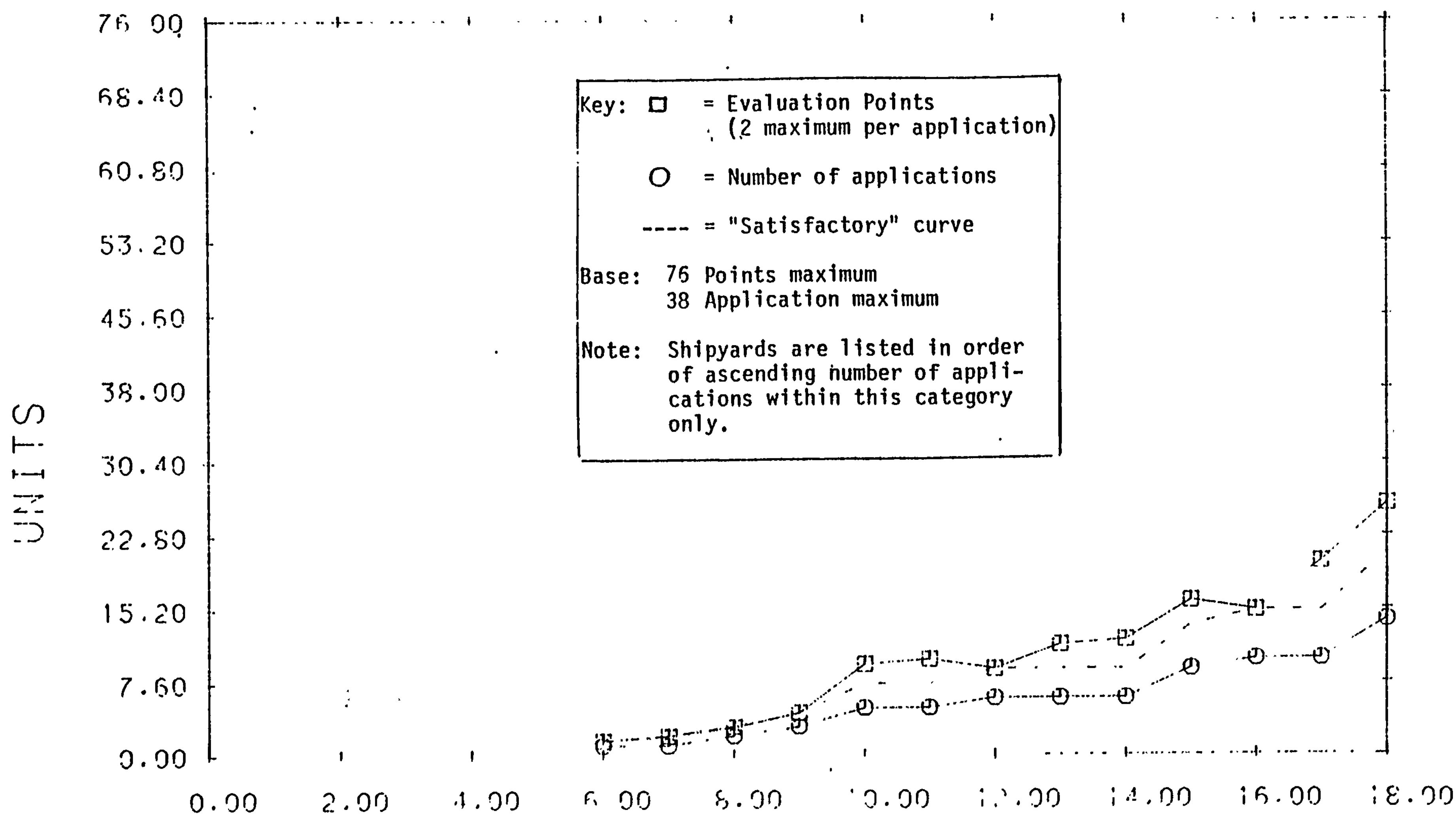

Figure 21. Shipyard N/C Process Control Evaluation

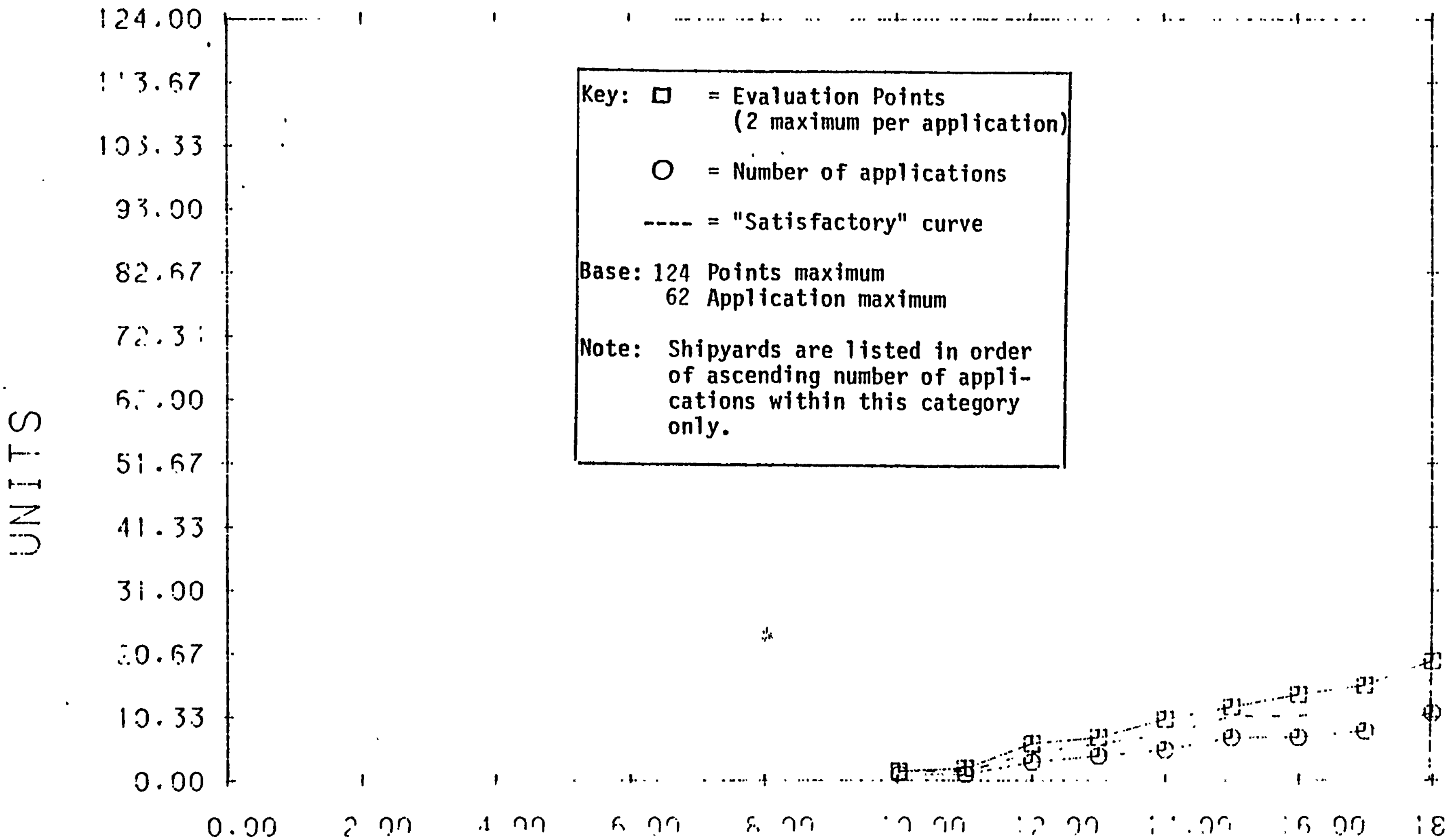

Figure 22. Shipyard Manufacturing Technology Evaluation

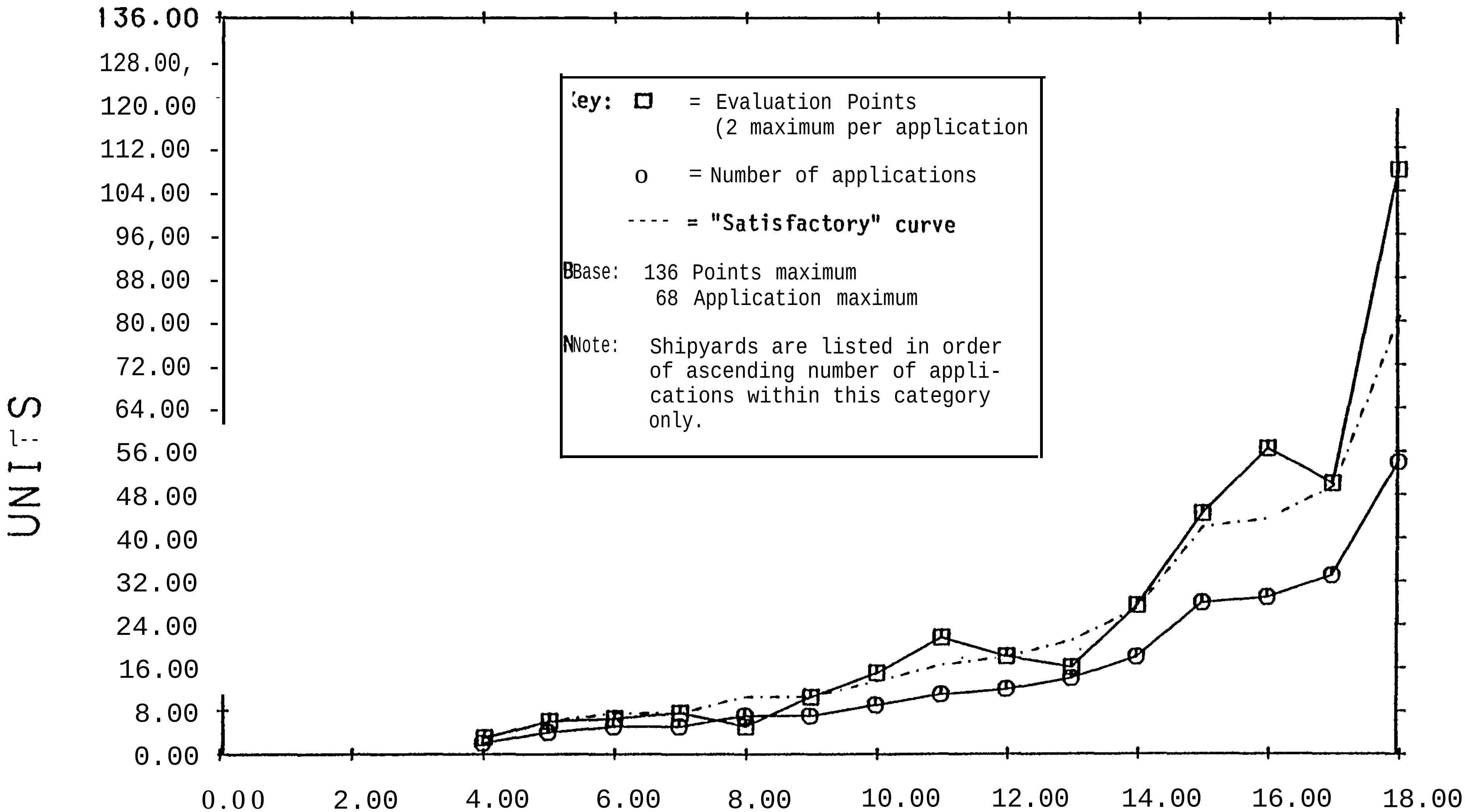

Figure 23. Shipyard Management Systems Evaluation

exhibit a great deal of satisfaction with their systems. In fact, the maximum number of applications, at 79 percent of potential, reports that their relatively new system is totally successful with 79 percent of the potential evaluation points (all pluses). The breadth or reach of the new system may be slightly exaggerated but it does show both confidence and control over their operations. The average was 22 points (16 percent) with an average coverage of 13 applications (19 percent).

2.3.3.6 Shipyard Automation Evaluation (Figure 24)

Only three shipyards reported using any form of automation. They ranged from 1 to 5 actual applications and 1.5 to 8 in evaluation points, respectively. Automation has not yet proven itself cost beneficial in the shipyards but those applying it have regarded the performance as satisfactory or better.

2.3.4 Absolute Trends in Design Agencies

As with the shipyards, each design agency surveyed is traced through its individual mix of systems and functional applications. As in the shipyard absolute trend analysis (Section 2.3.2), design agency graphs in Figures 25 and 26 have consistent symbols, each representing a specific, though anonymous, design agency. Systems and functional trends are more easily covered for design agencies than for shipyards for several reasons. There are four participating design agencies compared to 18 shipyards, there are 110 design . agency specific functional areas versus 244, and finally design agencies are only computerized in three major CAD/CAM technology areas and four major shipbuilding functional areas verses six and seven, respectively, for shipyards.

Design agencies show clear levels of application by CAD/CAM system type, Figure 25, and by functional application categories, Figure 26. There is not a great deal of absolute difference between the design agencies if viewed in ascending or descending order, however there is a significant difference from the lowest to the highest. Design agencies have different requirements for running their business than shipyards and this is reflected in the low number toring system, which specify hours spent compared to a given budget, rather than work-monitoring and/or control (e.g., drawing schedule vs. progress as

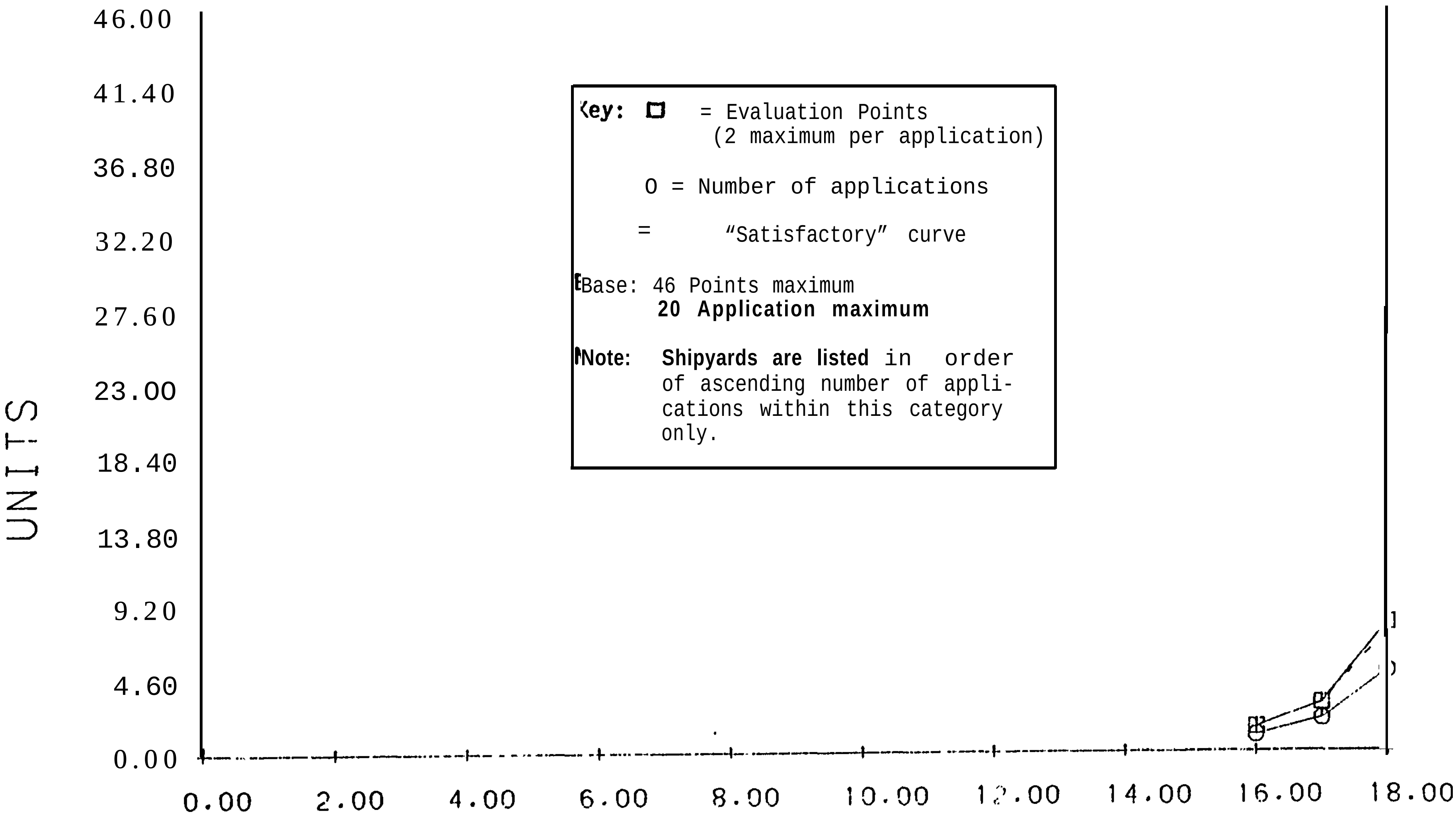

Figure 24 Shipyard Automation Evaluation

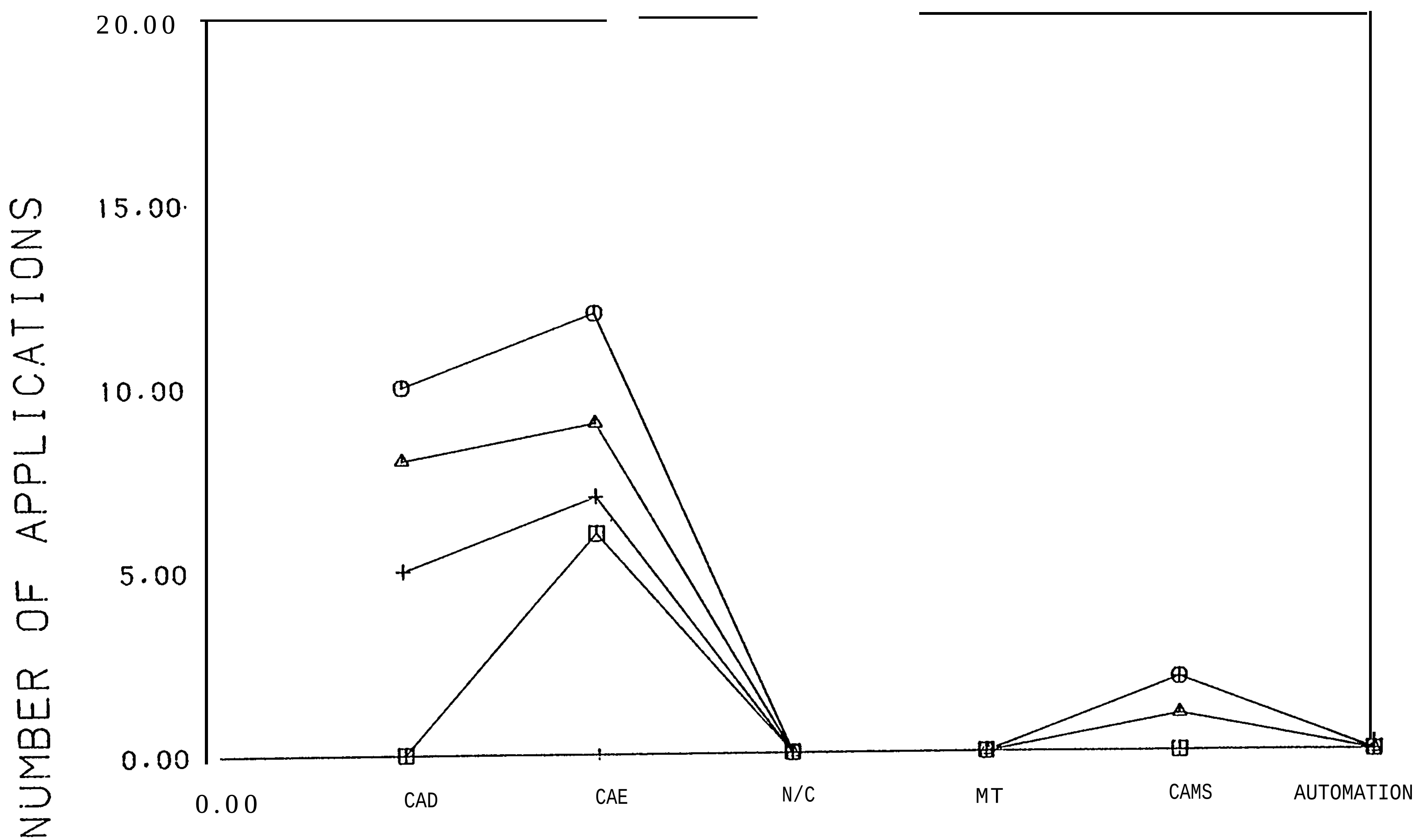

Figure 25. Systems Application by Design Agent

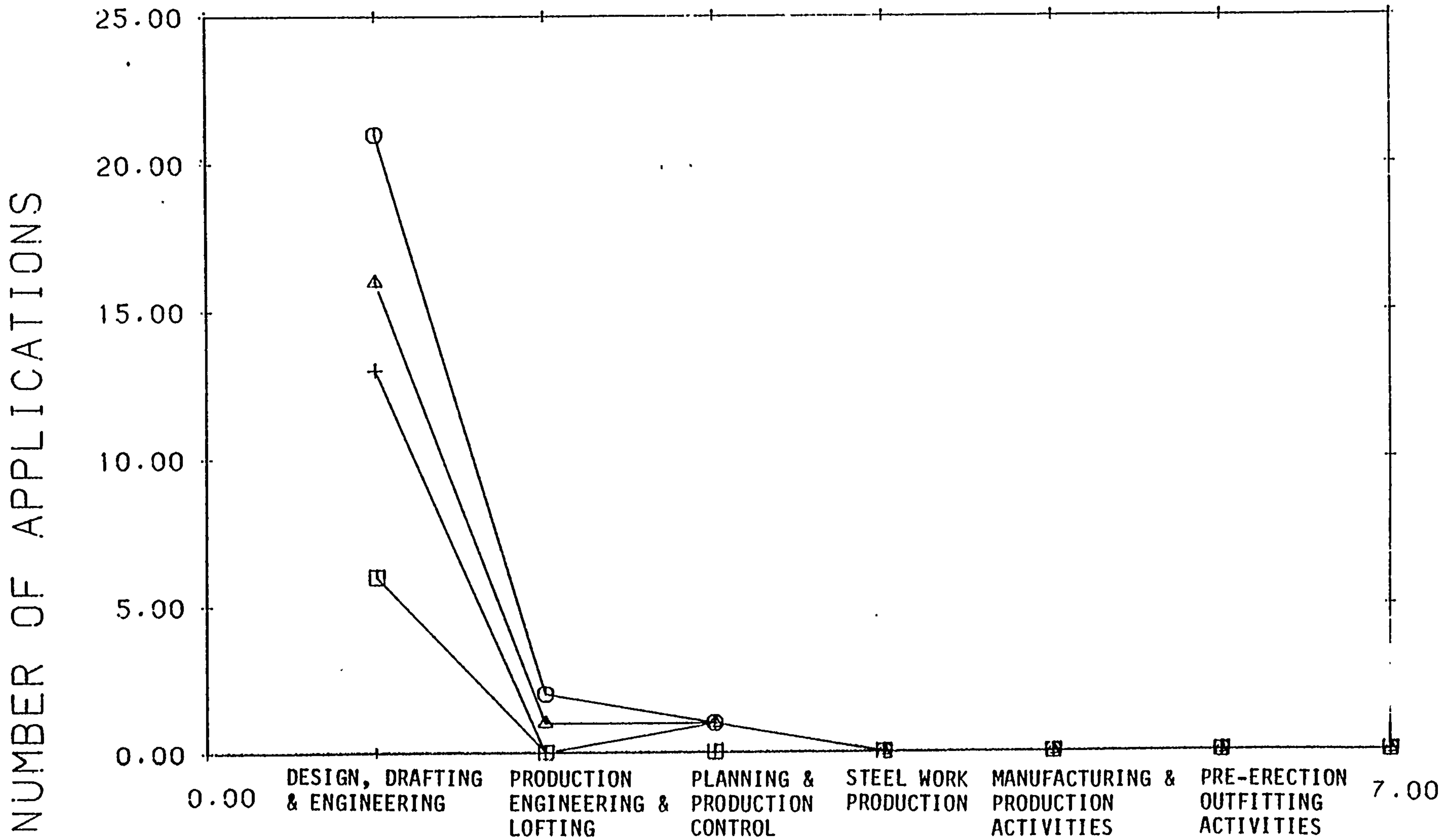

Figure 26. Functional Application by Design Agent

well as total labor figures). Shipyard and design agencies seldom control the drafting department via computer aids as they would a production environment when, in fact, both produce a product.

A design agency has minor internal needs for computer assisted planning and production control compared to a shiyard, and as shown in Figure 26 there are only three computerized applications. It would have been legitimate to expect more in this area on the assumption that a design agency might have been a logical source for some scheduling and planning computer time-sharing services, since many do currently offer scheduling/planning (apparently all manually), assistance to shipbuilders. On the other side, however, is the fact that not even larger shipyards use computer assistance (e.g., decision support tools) in the initial estimating/planning stages (section 2.3.2.2) so there appears to be no ready market for such services even if they did exist. There is no immediate future plans to expand in this direction either.

If asked what CAD/CAM technologies could affect the highest productivity gain at a design agency a logical answer would be CAD drafting systems and computer assited engineering analysis programs. In fact, there are the primary sources of CAD/CAM technology in use at design agencies today. Although the actual use of-CAD technologies is less than in many shipyards (average coverage is slightly below the shipyard's), the total coverage of design, drafting, and engineering is more than most shipyards (and the average coverage is higher as well). Integration and/or interface of drafting and engineering systems, however, is no further advanced than in shipyards (refer to 3.4.4).

2.3.5 Design Agency Evaluation of Systems Application

The design agency evaluation is conducted in exactly the same manner as the shipyard evaluation in section 2.3.3. The design agencies' responses to Part I of the CAD/CAM survey questionnaire were assigned these values: plus received 2 points; check, 1.5 points; minus, 0.5 points; and N (for new) received 1 point. A design agency was scored over 110 possible applications (refer to Appendix E) and 220 possible evaluation points.

Overall, evaluators were satisfied with their current system performance to date but are not overly impressed with them, as is shown in Figure 27, Design Agent CAD/CAM Evaluation. This is definitely the case with CAD technology evaluation, Figure 28, since they have also received almost all satisfactory marks. There are currently 23 total CAD technology applications (21 percent of potential CAD applications) scoring 16 percent of the possible evaluation points with a maximum range of 10 applications (37% of potential applications). There are 17 future CAD applications planned, which will almost double their current standing.

Computer aided engineering software has been in use longer than CAD drafting systems (and other CAD technologies) in all four cases. Shipyards feel that more of their CAE progams have been successful than any other CAD/CAM technologies, although there is one shipyard that has been dissatisfied with their production engineering application. CAE is the most established technology not only because it has more applications than the others, but also because there are fewer future implementations planned (l). This may imply that an average of 34 percent of the potential applications (34 actual applications) is currently a preferential position to be in. In other words, it is adequate coverage for engineering analysis.

Computer assisted management systems, Figure 30, ar performance to date but are not overly impressed with them, as is shown in Figure 27, Design Agent CAD/CAM Evaluation. This is definitely the case with CAD technology evaluation, Figure 28, since they have also received almost all satisfactory **marks.** There are currently 23 total CAD technology applications (21 percent of potential CAD applications) scoring 16 percent of the possible evaluation points with a maximum range of 10 applications (37% of potential applications). There are 17 future CAD applications planned, which will almost double their current standing.

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Computer assisted management systems, Figure 30, are evaluated at an average of 6.5 points (4 percent of potential) with only five applications (6 percent of potential) covered. Of the five current applications, two are new, both at one design agency, which accounts for the one score below the satisfactory level.

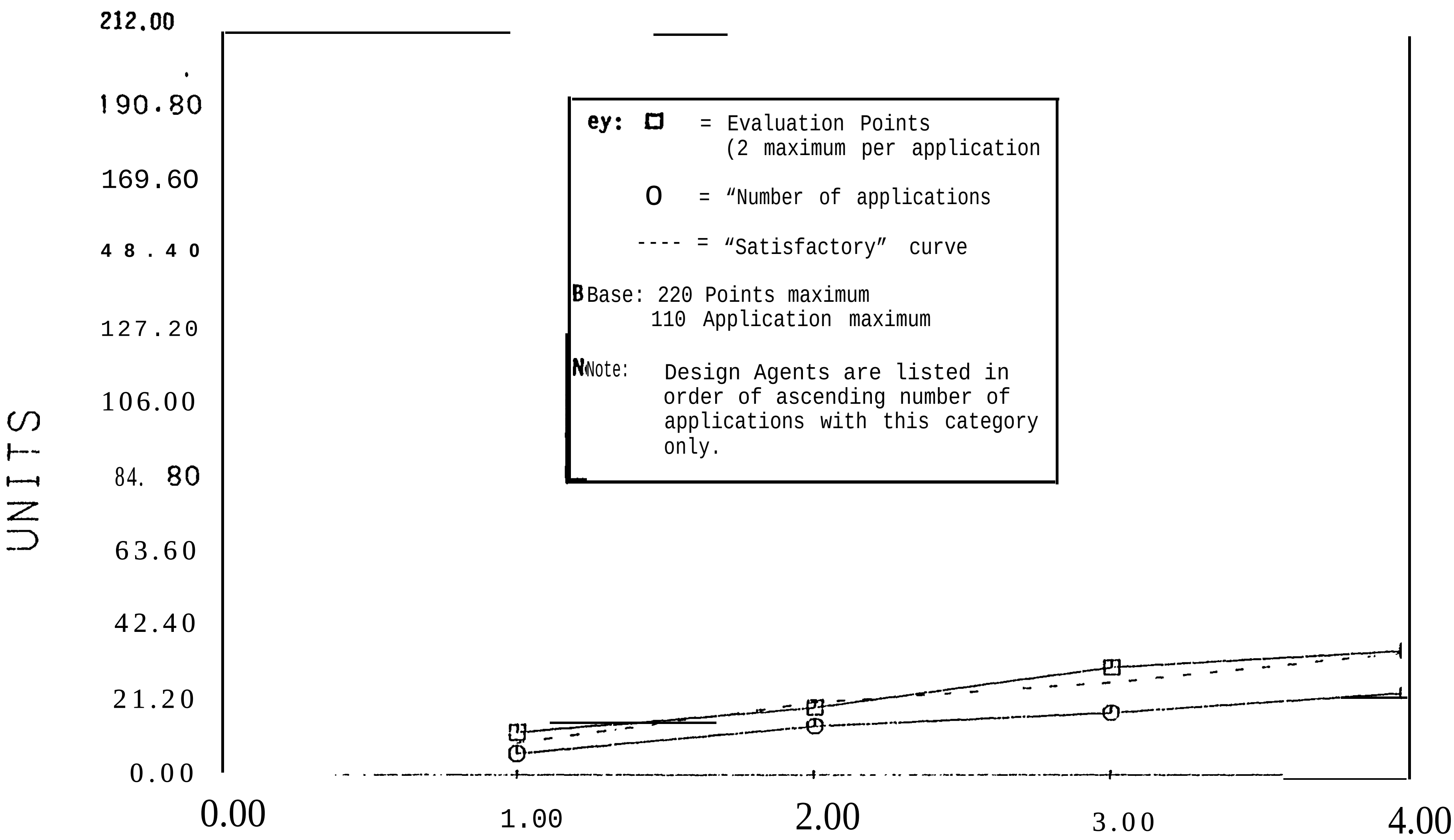


Figure 27. Design Agent CAD/CAM Evaluation

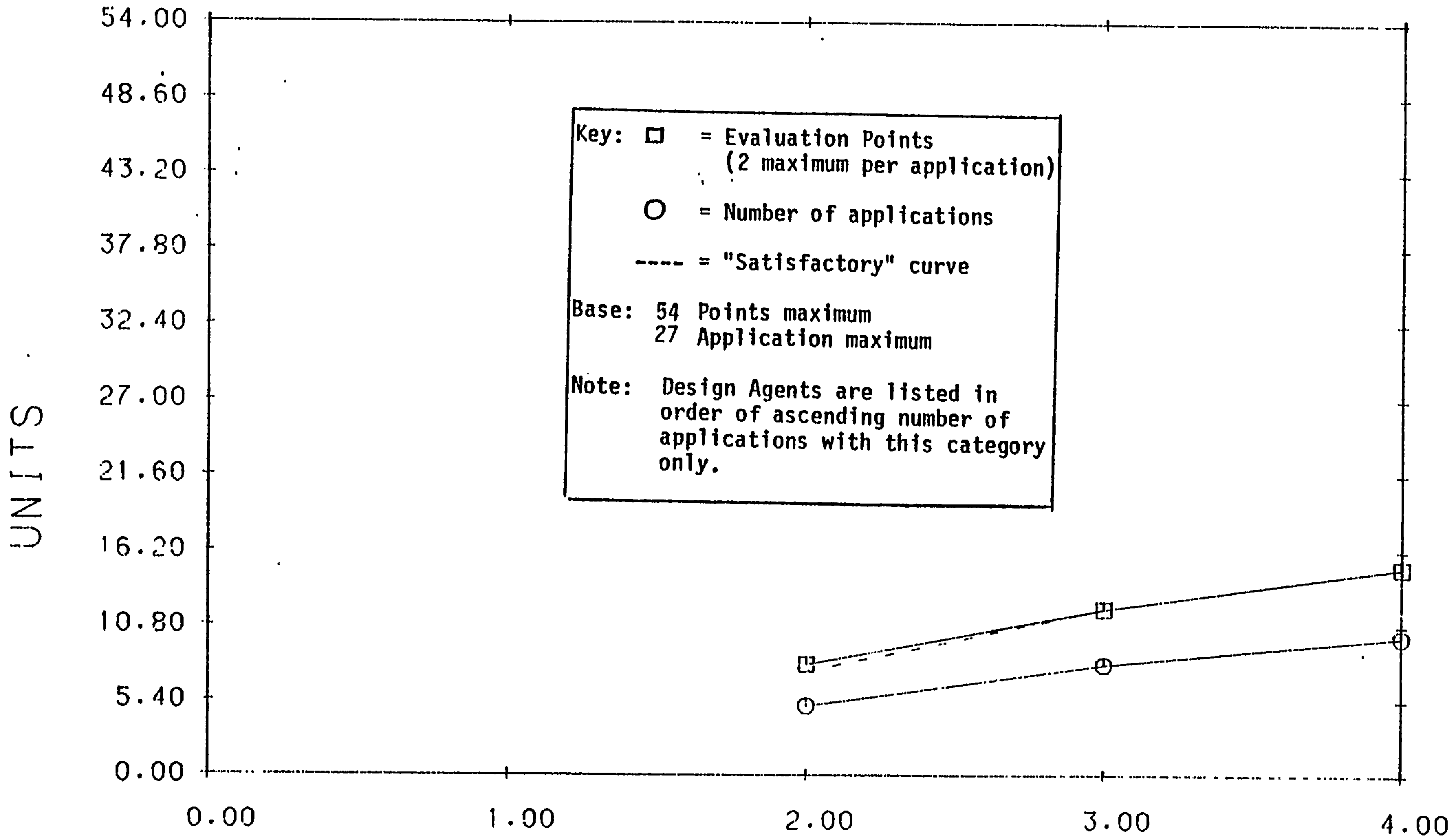


Figure 28. Design Agent CAD Evaluation

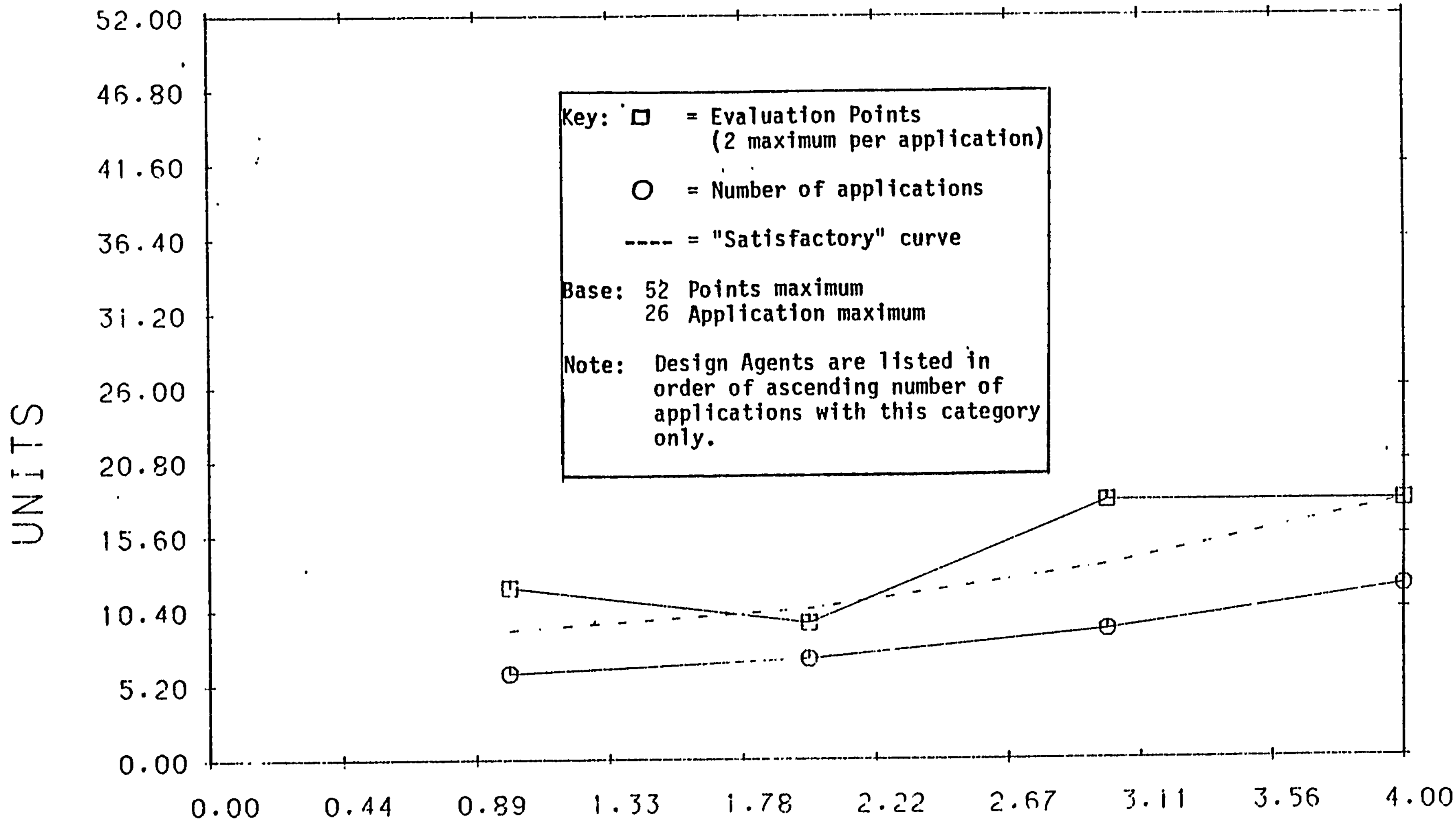


Figure 29. Design Agent CAE Evaluation

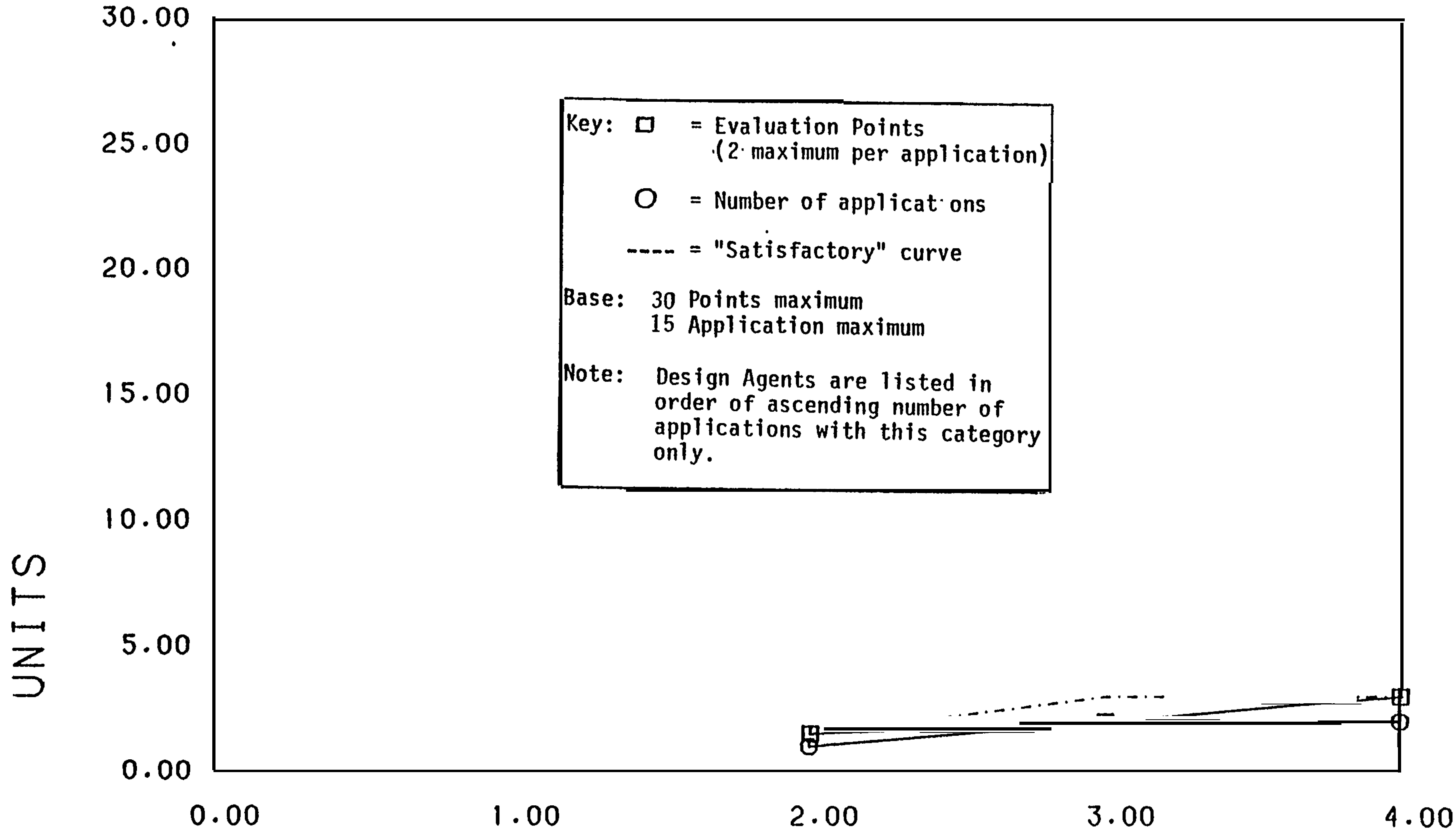


Figure 30. Design Agent Management System Evaluation

3. SOFTWARE EVALUATION

In part II of the questionnaire, Computer Technology Application Details, all users, shipbuilders, and design agencies, are considered together to evaluate the many aspects of vendor furnished and in-house developed software packages. The goal is to develop a more thorough understanding of the computer technologies in actual use in the U.S. shipbuilding industry. The objectives of this software evaluation are to:

- Determine which software packages are in use and provide a current evaluation of the historical performance of the various software.
- Provide a qualitative rating of how well a specific system has fulfilled its mission.
- Evaluate the level of integration of current computer systems.
- Establish the scope (application range) of most systems.
- Determine the in-house capabilities of most shipyards.
- Identify which areas were not covered by commercial software packages.

The following sections will discuss each area respectively.

3.1 SOFTWARE SURVEY

The questionnaire requested the evaluators to indicate which software package(s) they used for each of 44 predetermined computer technology categories, and provided extra room to add any other systems they felt were not called out (see Table 10, Part II Computer Technologies). For each software package they were asked to identify the shipyard functions that it affected, whether they had modified the software in-house, which other software systems it was integrated with, the number of years it had been in use, and a qualitative rating (from 1 to 10 with 10 being the best) of the package’s success. The tabulation of these data based on the insight gained through the shipyard visits provides necessary information by which to make a meaningful evaluation of each software package and each computer technology category.

TABLE 10. Part II. COMPUTER TECHNOLOGIES

The six general Computer Technology Areas which are covered in this survey appear below. A listing of the specific technologies within each area is also given. The respondent is encouraged to review this section before completing Parts I and III of the questionnaire. This information will be useful in categorizing specific computer technologies being applied to the shipbuilding functions into one of the six general areas.

I. Computer Aided Design

1. Automated Drafting
2. Bill of Materials Generation
3. Computer Aided Hull Definition
4. Computer Aided Hull Fairing
5. Group Technology
6. Interactive Graphics
7. Parts Definition
8. Solids Modeling

II. Computer Aided Engineering Analysis

9. Heat Transfer Analysis
10. Hydrodynamic Analysis
11. Hydrostatic Analysis
12. Material Analysis
13, Structural Analysis
14. Vibrational Analysis

III. N/C Process Control

15. N/C Cutting
16. N/C Frame Bending
17. N/C Machining
18. N/C Pipe Bending
19. N/C Programming
20. N/C Shell Plate Development
21. N/C Tape Verification
22. N/C Welding
23. Surface Preparation and Coating

IV. Manufacturing Technologies

24. Computer Aided Die Design
25. Computer Aided Lofting
26. Computer Aided Parts Nesting
27. Computer Aided Process Planning
28. Computer Time Standard Generation
29. Group Technology

V. Computer Assisted Management Systems

30. Control/Status Reporting Systems
31. Facilities Planning
32. Plant Layout
33. Economic Evaluation
    Materials Requirements Planning
35. PERT/CPM
    Planning Systems
37. Production Crew Assignment/Loading
38. Quality Assurance Systems
39. Scheduling Systems

VI. Automation

40. Automated Materials Handling
41. Automated Storage and Retrieval
42. Flexible Automated Mfg. Systems
43. Instrumentation and Testing
44. Robotics

3.2 POSSIBLE SURVEY BIAS

The only way to make the specific vendor ratings meaningful is to review the types of biases that can unintentionally affect the evaluator (interviewee or questionnaire respondent) and thus the evaluation at each shipyard and design agency. This is a form of performance evaluation and therefore can contain all of the traditional biases:1

a) The halo effect. One of the systems might be the evaluators pet project and thus receive a higher rating than it should. The opposite could also be true, it could be the evaluators pet peeve and therefore receive a low rating. Observation suggests that only an occasional system was conspicuously higher than others on the same survey form. If anything, more were conspicuously low.

b) Standards of evaluation. Some evaluators' view of a successful application may be different than that of other evaluators. Therefore on a scale of 1 to 10 a 9 could be excellent to one person whereas a 10 might be to another. Observation suggests that most evaluators scored roughly over the same range on this survey, though that does not rule out this bias factor.

c) Recent Behavior Bias. The experience the evaluator last had with a system might shade their view of that package's overall performance. For example, if the package just lost a months worth of work that person might not look too favorably on it even it has saved the company money in the long run. The opposite is also possible.

d) Central Tendency. This is the tendency to rate everything close to "average" or "good" as opposed to using the full range of the scale to evaluate performance. This is the most applicable bias for the software rating system. The cental tendency of the 1 to 10 scale in this case was 7.5.

e) Statistical Bias. When only one or two evaluators rate a system it will not reflect as much of a consensus as when 10 do. Also, the same is true for the number of applications a system has. For example, SPADES fits into many different analysis categories giving it a more thorough overall review than a package that is only in one category (e.g. the MarAd Heat Transfer Analysis program), because more of its characteristics are being evaluated. In this survey packages with only one application. and only one user have not been reported unless it constitutes a unique application.

Even though the potential for biased ratings seems high, the actual bias is considered to be quite low based on the visits (roughly one-half of the shipyards were visited). The ratings were reviewed during or directly after - each shipyard/design agency visit and screened by the research team. In most cases the figures tended to reflect the observed attitudes of the shipyard as a whole, not just the evaluator.

The most relevant bias is the central tendency. In this survey the average for all packages and the central tendency are roughly the same at 7.5, which can be considered a reasonably successful systems application. The main range of results were between 6 and 9 so while a 6 is still a successful implementation according to the rating scale, it is at the low end qualitatively, whereas a 9 could be considered very successful. Anything below a 5 might need serious review before considering it a useful implementation (except when statistical bias enters in).

3.3 SOFTWARE/VENDOR EVALUATION

Table 11 ranks the software packges in order of evaluation points and then within each evaluating range by user rating. An evaluation point is an application that was rated. This means, one user having three different applications of a package would produce three evaluation points and/or one application category with five user ratings provides five evaluation points. The more evaluation points the more objective the evaluation. Also, the more users the more objective the evaluation. The categories with five or more evaluation points, SPADES through McAuto in the table, provide a very reliable rating of the historical usefulness of each software package for the U.S. shipbuilding industry. There were approximately 20 software packages with only one evaluation point. These have not been included in Table 11 because their ratings are highly subject to bias, instead they have been listed, in order of rating, in Table 12.

3.3.1 SPADES

SPADES received the most thorough evaluation of any single software package. Thirty-nine evaluation points based on five users (i.e. evaluators/ shipyards) and an average implementation life of 8.23 years tend to suggest that it was also-the most unbiased review. To have received an 8.19 performance rating under these conditions strongly suggests that it has been, historically, a very successful implementation. Since this package is applied over several shipyard functions, Table 13 provides a more specific look at its individual task performance ratings.

TABLE 11. SOFTWARE EVALUATION

Evaluation Points	Software Package	Primary Application Area	User Ranking	Avg. Yrs	Approx # of Users
E>20	SPADES	N/C & Lofting	8.19	8	5
E>20	In-House	MIS	7.4	6.5	12
10<E~20	Control Data Corp.	CAE	7.7	4.5	4
l0<E<20	CADAM	CAD	7.4	2.5	5
10<E<20	AUTOKON	N/C & Lofting	7.25	4.	3
5≤E≤10	NASTRAN	CAE	8.25	6.5	5
5≤E≤10	KONGSBERG	N/C & Lofting	8.00	6.2	5
5≤E≤10	STRUDL	CAE	7.9	4.5	5
5≤E≤10	AUTO-TROL	CAD	7.1	3	3
5≤E≤10	McAUTO	CAE-N/C	6.86	5.43	3
1<E<5	VISION	MIS	9.0	3	1
1<E<5	NAVY	CAE	8.04	10.	1
1<E<5	NSRDC	CAE(Hydrodynamic)	8.0	6.	2
1<E<5	SHCP	CAE(Hydrodynamic)	7.7	4.5	5
1<E<5	ARTEMIS	PERT/CPM	7.5	1.	2
1<E<5	UNIGRAPHICS	CAD	7.25	5.	1
1<E<5	Bendix (Controller)	N/C	7.0	4.	2
1<E<5	Cincinnati Milicron (T-3 Robot)	Automation	7.0	1.5	1
1<E<5	SPAR	MIS	6.25	1.5	2
1<E<5	NAVSEA	CAD-CAE	6.0	3	3
1<E<5	HULDEF	CAD	6.0	4.5	2
1<E<5	IBM	MIS	6.0	7.5	3
1<E<5	INFO	MIS	6.0	3	1

TABLE 12. SOFTWARE EVALUATION LIST FOR ONE OR LESS EVALUATION POINTS

Evaluation Points	Software Package	Primary Application Area	Avg. Yrs
E = 1	DYNAL	CAE (Strut)	NR
E = 1	Allen Bradley	N/C (cutting	9.00
E = 1	EASE 2	CAE (Struct)	10.00
E = 1	GBRP	CAE (Vibr.)	4.00
E = 1	Heath (N/C controller?)	N/C (mach)	9.00
E = 1	MARAD	CAE (Heat Trans)	NR
E = 1	Tests & Trials	Auto(Testing)	4.00
E = 1	UCC (Apt	N/C (verif)	12.00
E = 1	Cybernation	N/C (cutting)	2.50
E = 1	MOST		
E = 1	Numeridex	N/C Mach)	1.00
E = 1	SEALOAD	CAE (Hydrodynamic)	1.00
E = 1	MOST	MIS	3.00
E = 1	Stru PAC	CAE (Struct)	9.00
E = 1	Swanson Anal	CAE (Struct)	4.00
E = 1	Systonetics	MIS (PERT/CPM)	2.00
E = 1	Telegrah	CAD (Inter. Graphics)	4.00
E = 1	Scores	CAE	8.00
E = 1	SAI (Sci. Appl. Int'l)	MT (GT)	1
E = 1	COPICS	MIS (B.O.D.)	3
E = 1	TSI Int'1 Project Monitor	MIS (crew Loading)	5
E = 1	ABS	CAE (Vibr.)	5

TABLE 13. SPADES PERFORMANCE RATINGS

Shipyard Function	User Rating	Average Years in Use	Number of Users	Evaluation Points
1) Drafting	6.5	6	2	2
3) Hull Definition	8	7	4	4
4) Hull Fairing	8.3	8	5	5
6) Interactive Graphics	9	15		
7) Parts Definition	8	5.5	2	1
TOTAL CAD RATING	7.96	8	4	4
11) Hydrostatic Analysis	7.25	7.5	4	4
TOTAL CAE RATING	7.25	7.5	4	4
15) N/C Cutting	8.5	9.25	4	4
16) N/C Frame Bending	7.5	9	2	2
19) N/C Programming	8.5	9	2	2
20) Shell Plate Development	8	8.33	4	3
21) N/C Tape Verification	8.33	7	4	4
25) Lofting	8.75	7	4	4
TOTAL N/C RATING.	8.33	8.4	4	18
26) Parts Nesting	8.75	7	4	4
TOTAL MANUFACTURING TECHNOLOGY	8.75	7	4	4
OVERALL TOTAL	8.19	8.23	5	39

SPADES primary contribution to computer aided design is hull definition and fairing, and, in at least two instances, its ability to link/interface with a CAD drafting system such as CADAM. There is no instance where SPADES is truly integratd to a CAD system and, so far, is only used to “send” its information (as opposed to receive it). The latter implies it must be used first to gain the benefit of the interface, which is not always the most desirable approach. However, its contribution to CAD based on its ability to define the hull structure and provide faired hull lines is high, 8 and 8.3, respectively, and has therefore historically satisfied a shipbuilding specific function not available from turnkey CAD drafting systems.

In engineering analysis SPADES rated a 7.25, (fair to good) for its hydrostatic analysis, but SPADES primary strength is in its N/C process control capabilities. Showing particular strength in lofting, N/C programming and cutting (or tape generation for cutting) and combined with its CAD strength, SPADES has been rated highly and distinguishes itself as the most widely applied vendor package in the survey.

3.3.2 In-House Programs

The category of in-house programs is a conglomeration of all in-house programming applications reported in the CAD/CAM survey questionnaire. These in-house programs tend to be on the larger end of development time, though some may clearly represent man-years of effort where others could be measured in man-months. There is no way to determine the exact level of effort in developing any one package but the more detailed breakdown of in-house applications, Table 14, adds insight to their overall usefulness.

In-house programs represent 78 applications across 12 of the 22 shipyards and design agencies surveyed. This means that approximately 30% of all software applications are attributable to in-house programs. In all cases, if viewed by major catgeory except CAE and N/C Process Control, in-house programs are rated less then average (below 7.5) which means their application has been successful, but-not overly so. Shipyard/design agent programming ability is diverse, a few programmers to full-fledged systems departments were observed on the shipyard visits (Appendix C). Most were on the small end of programming personnel.

TABLE 14. IN-HOUSE DEVELOPED SOFTWARE PERFORMANCE RATINGS

Shipyard Function	User Rating	Average Years In Use	No. of Users	Evaluation Points
3) Hull Definitiion	4.5	7	2	2
4) Hull Fairing	6.5	11	2	2
6) Interactive Graphics	NR	4	2	0
7) Parts Definition	9	11	2	2
TOTAL CAD	7	9	5	6
9) Heat Transfer	7.5	5.5	2	2
10) Hydrodynamic Analysis	8.67	10	4	3
11) Hydrostatic Analysis	8.2	8.4	5	5
12) Material Analysis	8	5	1	1
13) Structural Analysis	8.5	5.75	4	4
14) Vibrational Analysis	7.5	7.33	3	2
TOTAL CAE ANALYSIS	7.78	7.2	*	17
15) N/C Cutting	10	10	2	1
16) N/C Frame Bending	NR	NR	1	0
19) N/C Programming	7.25	6.25	4	4
20) Shell Plate Development	8.33	9	3	3
21) N/C Verification	8	4.67	4	3
22) N/C Welding	NR		1	0
25) Lofting	9	11	2	2
TOTAL N/C PROCESS CONTROL	8.15	7..5	*	13
26) Nesting	8.67	10.67	4	3
27) Process Planning	NR	NR	1	0
29) Group Technology	NR	NR	1	0
TOTAL MANUFACTURING TECHNOLOGY	8.67	10.67	4	3
2) Bill of Materials	6.5	6	3	2
28) Time Standard Generation	NR	NR	1	0
30) Control/Status Reporting	7.29	6	7	6
31) Facilities Planning	6	3.5	2	2
32) Plant Layout	5	4	1	1
36) Economic Evaluation	9	3	1	1
37) MRP	6.4	3	4	4
35) PERT	5	1.5	2	2
36) Planning	7.25	3.5	3	3
37) Crew Assignment	6.33	3.67	3	3
38) Quality Assurance System	6.5	5	3	2
39) Scheduling	7.4	7.25	5	5

TABLE 14 (cont.)

Shipyard Function	User Rating	Average Years In Use	No. of Users	Evaluation Points
OTHER RELATED PKGS;				
Contract Purchasing	9	3	1	1
Tool Inventory	8	1	1	1
Structural Steel Planning	7	8	1	1
TOTAL CAMS	6.86	4.35	*	1
40) Automated Material Handling	NR	NR	1	0
TOTAL IN-HOUSE PERFORMANCE	7.37	6.33	12	78

Reviewing Table 14 there are some patterns that are worth noting. The first is the relative age of the software. In all main categories, except management systems, the average age of the software is over seven years. The success ratings are higher for the more mathematically based applications such as engineering analysis and N/C. The management systems are more recent than any other group and are rated the lowest.

A well defined problem statement and very structured decision rules, such as in engineering are more easily identified and computerized than the more judgment-oriented decisions of management. Closer review shows that in-house CAD software is more interface oriented or pre-graphics system(s) developed than engineering packages, which are primarily a total applications processor (e.g., heat transfer analysis vs. SPADES - CADAM interface(s)). Management systems are more recent because they are constantly being revised to fulfill changing demands, with total revisions necessary on occasion to clean-up the system.

Management systems represent the largest in-house development efforts by most shipyards. This was not entirely by choice since vendor off-the-shelf management systems did not accommodate shipbuilding requirements, especially the emphasis on construction and the size (data base) requirements. Few vendor systems do today. Most shipyards consider their in-house systems to be marginally successful but confess that there is a lot of room for improvement. As a result of the large number of in-house scheduling and control systems (vs. vendor supplied) there is a continual upgrading and expansion process occuring at many shipyards. Observation suggests that while U.S. shipyards are several years away from a totally closed-loop (e.g. management comparison and feedback) system, they are evolving toward it with each major modification and/or new system they develop. Evidence of this is the fact that more first-line supervision is coming in day-to-day contact with management information systems today than five years ago, thus beginning to close the loop around the real time, real world constraints of the actual production activities.

It should be noted that of the four design agents surveyed only two have demonstrated in-house software development capabilities and these are only in the engineering analysis areas. Though they plan to integrate CAD and CAE they are not as far along as some of the shipyards.

3.3.3 Software with 10 to 20 Evaluation Points

3.3.3.1 AUTOKON

AUTOKON has the most applications in this category (19) represented by 16 evaluation points (and 3 no-ratings). It is the second most thoroughly evaluated vendor package in the survey. AUTOKON'S primary usage is in hull definition and fairing, and N/C process control as shown in Table 15. The applications this package serves are similar to SPADES and, therefore, Table 15 includes a column for the SPADES user ratings for comparison purposes. AUTOKON is rated highly in its primary objective areas; hull definition and fairing, N/C cutting, N/C programming, N/C tape verification, lofting, and nesting. Users rate its interactive graphics, hydrostatic analysis, and shell plate development at the low end of the successful scale. AUTOKON's apparent handicap is its inability to interact in a user friendly fashion at the graphics terminal. Thus would tend to bring down the ratings of hull definition, and fairing, parts definition, and shell plate development. Overall, AUTOKON is considered a successful software package by its implementers/users and it is serving a vital shipbuilding specific role in the U.S.

AUTOKON and STADES are providing shipbuilding with lofting, nesting, and N/C process control that no other software packages available in industry are. This is not because these capabilities do not exist in other software, but primarily because these two packages have been effectively tailored to the shipbuilding industry. In a sense this is a luxury not true of many other vendor's packages due to the limited customer base. Two other attempts have been made to satisfy these same applications. The first is Unigraphics tied to APT, however this is much more part definition-oriented than hull structure and lofting-oriented and is used primarily in a repair yard's N/C shop operations. The other is an attempt at in-house programs combined with a Kongsberg system, but this is a very old and very limited approach and falls short of competing with SPADES or AUTOKON.

OVERALL TOTAL	7.25	4.26	3	16	8.14.

3.3.3.2 CADAM

The Computer Aided Design and Manufacturing (CADAM) system is the most prevalent drafting package in the U.S. shipbuilding industry. CADAM is a 2D (2-1/2D artificial view) "CAD/CAM" system whose strengths lie in its drafting user friendliness and its ability to handle large projects (data storage, retrieval, and manipulation). It is used quite literally as a drafting package even though it has the ability to simulate a cutter path and generate N/C tape. There is no indication that these N/C features are used by any of the four shipbuilders or one design agent surveyed. The reason is that four users have SPADES for these functions and the other shipyard simply does not indicate that they have any N/C equipment at all. One of the shipyards indicates a one-way interface from SPADES to CADAM (Appendix E, Shipyard M) whereas the three other users would need to duplicate the hull definition data manually.

As a drafting system, CADAM rates an 8, with an average of 2.83 years in use. This breaks down more specifically into a drafting, interactive graphics, and parts definition with user ratings of 7.8, 8.5, and 8, respectively. CADAM's overall average is biased downward by two users' low rating on bill of material-s generation capabilities (both 5s) resulting in a 7.4 user success rating and 2.6 years in use. No other CAD system scored this highly on its drafting capability.

3.3.3.3 CDC

The CAD/CAM survey questionnaire requested that the evaluator indicate the software vendor, and while most specified the software package name a few supplied only the vendor name. This is the case with the Control Data Corporation (CDC). The four shipyards that used either CDC's software packages directly or via time-sharing service did not indicate specifically which one(s). One user rated CDC as an 8 consistently and was the only user for drafting and interactive graphics, 1 year; heat transfer, hydrodynamic, hydrostatic, and material analysis, all 5 years. Three users ranked CDC's structural analysis with an 8, 6, and a 9 for an average of 7.67 (and 5.33 years); and two users ranked their vibrational analysis with an 8 and a 6 for an average of 7 over five years. The one user tended to bias the ratings upward for an overall average of 7.73 success rating, but even if adjusted it is respectfully close to the median rating (7.5) and indicates successful categories.

3.3.4 Software/Vendor With 5 to 10 Application Points

NASTRAN was rated an 8.4 over 6.6 years for structural analysis (five users) and 8 over 6.7 years for vibrational analysis (three users), averaging an 8.25 success rating, making it the highest rated software package. Kongsberg represents primarily a large bed plotting table and/or software for N/C proveout and machine control. Its overall rating is an 8 over an average 6.2 years and provides plotting, N/C cutting, N/C machining, and N/C tape verification (visual via the plotter). Konsberg's rating is biased by one user rating it a 10 and if adjusted would be approximately a 7, which is still good. This equipment is largely outdated compared to today's technology but was the state-of-the-art ten years ago. STRUDL is a software package comparable to NASTRAN and is almost as highly rated by its users. STRUDL received an 8.2 over 4.5 years of use (five users) for structural analysis and a 7 over 4 years (two users) for vibrational analysis, averaging 7.86 overall; in other words, a very successful package.

ANVIL 4000 is only being used by one shipyard surveyed and observation suggests that it is not in full production use (refer to Appendix C, Shipyard O), due to slow response time and discontinued support of the RAMTEK graphics terminal. Despite the pitfalls, the evaluating shipyard rates it a 7.71 over their 2 years experience with it. ANVIL 4000 evolved out of AD 2000 and is a software program (as opposed to a turnkey system), which can run on designated mainframe computers and is a 3D system. In addition to the drafting aspects of the system (receiving a 7.33 average rating), they have used the N/C portion of the package for N/C cutting, N/C programming, lofting, and parts nesting (9.97 respectively) and provide a crude interface to AUTOKON through the APT CL (NC center line data) file. Even though they rate it highly, the user indicates the desire to utilize a different system for new ship production and rework.

AUTO-TROL is used by two design agents and one shipyard and is being reviewed for implementation by at least one other shipyard. It has 20 and 3D capabilities and so far has only been used for drafting (6.67 rating over 3.17

years) and interactive graphics (8 rating over 2.75 years) even though it supports N/C via APT formats. It has an overall success rating of 7.1, slightly below average, over 3 years average use. Its bill of material generation features were rated a 7 by the two design agencies evaluators.

McAuto is another case were a vendor has been specified instead of a specific software package name. McAuto's services/software are being used for structural and vibrational analysis (an 8.67 rating, 3 users, 5.67 years and a 9 rating, 2 users, 7.5 years) usually in combination with NASTRAN, STRUDL (see section 3.3.5), and/or in-house programs doing the same. Since it is not expected to do the whole job, this could account for the high rating for CAE of 8.8 which is a very successful implementation indication. McAuto is also indicated as being used for N/C cutting, machining, pipe bending, and programming though a no-rating was given on its performance in these areas. McAuto has a package called MSCS and is used by one shipyard for PERT/CPM-type analysis and scheduling. However, the rating here is a 2, which is extremely low implying, at least, one user's negative experience with MSCS. This low rating also tended to lower the overall McAuto rating to 6.86 over an average 5.43 years duration. Clearly, the engineering analysis is strong and should be noted, whereas MSCS might not be a useful scheduling tool for the shipyard but with only one opinion it could easily be a biased interpretation.

3.3.5 All Other Software Packages

SoftWare packages and vendors with less than 5 evaluation points have a high potential for being biased, either up or down, and therefore the application success rating is not very useful. However, the software being used at the various shipyards and design agencies is relevant and therefore this section will provide selective discussion of the software in Tables 11 and 12.

VISION and INFO are a scheduling package and query language, respectively, distributed by the PRIME Computer Company and are discussed in Appendix C, Shipyard O, Section 5. VISION was rated highly at a 9 over 3 years of use in. PERT/CPM, planning, crew loading, and scheduling. SHCP (Ship Hull Characterization Program) is used by four shipyards and one design agent for hydrostatic analysis and was rated at 7.67 by three of the survey respondents. ARTEMIS and SYSTONETICS were successful PERT/CPM type implementations at a 7.5 rating for two users and an 8 for one user, respectively. These are very recently acquired systems averaging 1.25 and 2 years, respectively. Unigraphics is a CAD system with particular strength in generating APT programs for N/C equipment. One shipbuilder surveyed uses the pacakge for their N/C shop activities. They are primarily an overhaul and repair facility. A Cincinnati Milicron T-3 robot is being used by one shipyard for investigation purposes. So far the conclusion seems to be that it is not feasible until a vision system is perfected, and even then it would need serious review to be cost justifiable. SPAR Associates, Incorporated is a consulting company which has developed partial management information systems for two shipyards covering planning (rated a seven over 5 years) in one case; and control/status reporting (rating a 7 over eight months), materials requirements planning (rated a 3 over four months), and scheduling (rated an 8 over eight months) in the other. HULDEF is being used by one design agent in conjunction with SPADES and one shipyard in conjunction with AUTOKON. Since three IBM PERT/CPM type systems were being used by three separate shipyards they have been consolidated into one category. JAS/3 rated a 7 by one shipyard, PMS rated a 5 by another, and an unspecified IBM PERT system rated 6 by a third yard. These are all relatively-poor showings.

Of those, software packages/vendors with only one evaluation point (Table 12) are potentially very biased (only one opionion) but they deserve mention. Tests and Trials is a software package used to simulate sea trials for a particular vessel. This is the only package of its kind identified in this survey. DYNAL, EASE2, GBRP, MARAD (heat transfer program), SACS, SEALOAD, STRU, SWANSON, STRU-PAC, SWANSON analysis system (used by two shipyards but only rated by one), SCORES, and ABS are all computerized engineering packages. All of which were rated above an 8 except SCORES, which received a 7 and ABS a 6. Allen Bradley, Heath, Cybernation, and Numeridex are all N/C controller companies. UCC, University Computing Company, is a time-sharing computer service company with an APT package available for N/C programming. MOST is an automated time standards generating package used in the sheet metal shop of one shipyard. This was the only surveyed case of using computer generated time standards and it was rated an 8 over three years of performance. T S I International’s Project Monitor (crew loading) and IBM’s COPICs (bill of materials) were rated very low, 4, over six and three years, respectively, in use. Telegraph is an interactive graphics package which was rated an 8 over four years, however the survey turned up very little information on the exact role of the package in the shipyard. SAI (Science Applications International) is the only vendor procured group technology package mentioned in the survey (one in-house developed computerized material's catalog was identified). Though it has only been in use for one year and rated at the low end of the application's success scale, 5, it reportedly covers the shipyard activities of welding, staging, pipe work, engine room machinery, hull engineering, and painting. This merits further investigation.

3.3.6 Summary of Software/Vendor Evaluation Section

Those systems with 10 or more evaluation points in Table 11 represent relatively objective application success ratings for the shipbuilding industry. Those systems with between five and 10 evaluation points can be considered fairly reliable user evaluations when more than one shipyard/design agent has rated them, though chances for some bias are greater. Software with less than five evaluation points can be used as a guide but cannot be considered objective statistics for both Tables 11 and 12.

SPADES is the most widely used numerical control/engineering system, followed closely by AUTOKON. CADAM is the most widely used CAD package and is used exclusively for drafting. More than half of the shipyards/design agencies surveyed have written substantial in-house programs; these cover most applications but concentrate mostly around management information and control systems. Some unique applications include MOST for time standard generation, Tests and Trials for sea trial analysis, and SAI for group technology analysis.

3.4 COMPUTER TECHNOLOGY COVERAGE BY CATEGORY

3.4.1 CAE and N/C

The two computer technology areas covered best, that is to the highest degree of satisfaction, are Computer Aided Engineering (CAE) and N/C Process Control (N/C) with a 7.9 rating over 7.5 years and 7.8 rating over 6.5 years, respectively (Table 16). All categories in CAE were covered by at least seven users except material analysis, which only had two. Though material analysis is important in some applications it is not a primary concern of a shipbuilder (except as already covered in structural analysis), and therefore is not to be

TABLE 16. TOTA L SOFTWARE COVERAGE MATRIX

	Computer Technology	Total No. of Users	Overall User Ranking	Avg. Years In Use
	CAD:			
1)	Drafting	15	7.5	4
2)	(B.O.M. is in computer assisted Management System's rating)			
3)	Hull Definition	10	6.125	3
4)	Hull Fairing	13	6.5	6
5)	Group Technology			NR
6)	Interactive Graphics	14	4	4
7)	Parts Definition	10	8.17	7
8)	Solids Modeling	2	NR	NR
	TOTAL CAD RANKING (WEIGHTED AVG.)	NA	7.3	5.5
	CAE :			
9)	Heat Transfer Analysis		8.4	8
10)	Hydrodynamic Analysis	7	8.2	8
11)	Hydrostatic Analysis	15	7.7	8
12)	Material Analysis	2	8	10
13)	Structural Analysis	16	8.2	
14)	Vibrational Analysis	13	7.6	6
	a) Weight Calculation	1	1	1
	TOTAL CAE RANKING	NA	7.9	7.5
15)	Cutting	14	8.2	6
16)	Frame Bending	3	7.5	9
17)	Machining	4	8	1
18)	Pipe Bending	1	NR	NR
19)	Programming	13	7.2	6.5
20)	Shell Plate Development	11	7.6	7.5
21)	Tape Verification	11	8	6.5
22)	Welding	1	NR	NR
23)	Surface Preparation	0	-	-
25	Lofting	11	7.9	6.5
	TOTAL N/C RANKING	NA	7.8	6.5
	MANUFACTURING TECHNOLOGY			
24)	Die Design	1	NR	NR
25)	(Lofting moved to N/C)			
26)	Parts Nesting	11	7.9	7.5
27)	Process Planning	1	NR	NR
28)	(Moved to MIS ranking)			
29)	Group Technology	2	5	1
	TOTAL MANUFACTURING TECHNOLOGY	NA	7.7	6.5

TABLE 16. (cont.)

	COMPUTER ASSISTED MANAGEMENT SYSTEMS			
2)	Bill of materials	9	6.125	3
28)	Time Standard Generation	2	8	3
30)	Control/Status Reporting	12	7.25	5
31)	Facilities Planning	2	6	3.5
32)	Plant Layout	1	5	4
33)	Economic Evaluation	1	9	3
34)	MRP	8	6	3
35)	PERT/CPM	10	6.[illegible]	4
36)	Planning Systems	9	7.5	4.5
37)	Production Crew Assignment/Loading	5	6.4	4
38)	Q.A. Systems	4	5	4
39)	Scheduling Systems	.9	6.9	5.5
a)	Contract Purchasing	1	9	3
b)	Sheet Metal Flat Pattern Development			
d)	Tool Inventory	1	8	1
	TOTAL MIS	NA	6.6	4
	AUTOMATION:			
40)	Automated Material Handling	1	NR	NR
41)	Automated Storage & Retrieval	1	NR	NR
42)	Flexible Automated Mfg. Systems	1	7	1.5
43)	Instrumentation and Testing	1	9	4
44)	Robotics	1	7	1.5
	TOTAL AUTOMATION	NA	7.7	2
	TOTAL COMPUTER TECHNOLOGY	NA	7.5	6

considered a major deficiency. Material analysis capabilities for unit and component parts might well be of greater importance to suppliers and subcontractors to the shipbuilding industry. Engineering calculations are the easiest to computerize and the number of different packages available (ranging from two to 12) and high user ratings in each area confirm that this is a well-covered category. N/C is similar to CAE in many respects. It is the most mature computer technology, originating for general industrial use in the mid and late 1960s and has been incorporated successfully into the shipyard, primarily for steel plate cutting. It has had limited application outside of steel plate work, however it has seen some application in general purpose machining, frame bending, pipe bending, and welding. While the trends in industry today are promoting robotics, the shipyards could still benefit from broader implementation of N/C (refer to shipyard O and P in Appendix C for evidence of this).

3.4.2 Manufacturing Technology and Automation

Qualitative success ratings for Manufacturing Technologies and Automation are misleading. Manufacturing technology as a category has been reduced (in this section) to die design, parts nesting, process planning, and group technology. Most of the rating for this category comes from 11 shipyards using computer assisted parts nesting. Computer assisted die design is of more concern to suppliers to the shipbuilding industry than to the actual shipyard, therefore need in this area is not great (in an overall monetary sense). Computer assisted process planning, however, is a state-of-the art application that has a lot of potential for shipbuilding. It would be an incredibly large undertaking for a whole shipyard, but could possibly be accomplished gradually beginning with the shop operations. Group Technology is not widely implemented in any construction and/or assembly based processes and therefore the shipyard evolvement in this area, though limited, is a positive indicator. If the shipbuilding industry pursues this area they will be at the leading edge in developing this aspect of the application. Many group technology (G.T.) ramifications have already come out of pre-erection outfit planning techniques and the trend towards these techniques in U.S. shipyards could have a great impact on-G.T. application.

Automation is misleading because there is so little of it. Due to the diversity of size and weight of ship components, most shipyards have approached material handling and automated storage and retrieval via special vehicles and general purpose storage spacing instead of automated systems. Perhaps some application of these systems will be found in the shops and work areas as more pre-outfitting is incorporated, though it is not a heavily demanded feature by most shipyards surveyed. Flexible manufacturing systems, in the broad sense, might be needed in the long term. Currently most shipyards cannot classify enough similar families of work to cost justify one. Instrumentation and testing are certainly important areas for automation; however, applications for this broad category are hard to define and are possibly a long term consideration. Certainly the sea trials analysis tool (shipyard O, Appendix C) is an important development in this area. Clearly, as ship electronic controls, monitors, and combat systems become increasingly sophisticated it becomes more important for the shipbuilder to have a way to test and trace problems in the equipment. Whether this is the responsibility of the buyer, supplier or shipbuilder will depend on the situation. Currently, the trend-in electronic equipment is towards the supplier. Robotics was rated as qualitatively successful but not currently cost justifiable. Robotics will have a very limited impact on the shipbuilding industry and is not expected to be useful in many applications, based on those surveyed.

3.4.3 CAD

Turnkey computer aided design (CAD) drafting systems are primarily a product of the 1970s, which have not yet finished evolving capability-wise. For example, solids modeling and standards such as the initial graphic exchange specification (IGES) are just now coming out of their infancy. Since shipbuilding requires a great deal of drafting and geometric analysis the industry has implemented CAD systems heavily since about 1978 and has been involved with computer geometric analysis since the early 1970s (e.g., SPADES, AUTOKON, APT). In fact, 68% of those surveyed, 15, have had CAD technology in place for about four years. Referring to Table 16 it is evident that the CAD category is well covered and the applications are reasonably successful with a 7.3 rating. One of the reasons that it is not higher is the lack of interface of CAD drafting systems with geometric analysis systems for hull definition and fairing. This means that ship structure needs to be defined into a minimum of two separate systems, which is neither efficient nor error free. Group technology (G.T.) for drawings, or a filing system based on part shape, is not a common practice in many industries and shipbuilding is no exception. The advances of G.T. are the reduction of duplication, increased standardization (to some extent), and primarily the savings in drafting labor; however, the easiest way to file drawings is by project and drawing numbers, and thus this is the norm. It would basically require an intelligent CAD operating system to file and/or que the draftsperson in the proper manner in which to make this successful. These do not yet exist on the scale necessary to contribute to a shipbuilding data base.

A few shipyards are experimenting with solids modeling. Solids modeling systems, as with most 3D systems, are not user friendly to draftsmen though they provide certain advantages in conceptual design and engineering analysis (e.g. interference checking, more life-like representation, offset viewing). The current bugs with solids modeling (and most 3D) systems is that they require a great deal of computer processing time, are not drafting-oriented, require more computer storage, and have difficulty representing complex surfaces. This is changing rapidly, however, for the near-term and most shipyards will be mostly involved with 2D systems because of the heavy demand for drafting. Some shipyards and design agents are considering using a system with both 3D and 2D capability or interfacing a 3D system with their current 2D system(s). The advantages to this are, basically, the ability to do preliminary conceptual design on the 3D system and, using the same data base, performing drafting on a 2D system.

3.4.4 Management Systems

Computer Assisted Management Systems (CAMS), often referred to as management information systems (MIS), represent the lowest user satisfaction, 6.6 application success, rating than the other categories. This is largely an objective self-criticism since most CAMS programs were developed in-house. In-house development was not totally by choice, but apparently a matter of non-availability of adequate systems. Attempts at vendor available integrated CAMS systems are just beginning to be introduced[2] and these are more suitable for high-volume electronics producers and manufacturing in general than a construction/assembly, low-volume situation such as shipbuilding. Why more of the discrete elements (such as MRP, economic analysis, etc.) of a shipyard CAMS are not vendor supplied is unknown. One clue is that most off-the-shelf systems (e.g. PERT/ CPM, MRP, control statusing, scheduling) are rated low, presumably because they do not adequately cover the shipbuilding environment needs, as opposed to being bad/inaccurate systems. Since these mangement systems are primarily in-house developed they tend to improve gradually over time (see Section 3.3.2, In-house Systems) and also the shipyard can better define its requirements (provided systems development has been handled in an organized fashion). With today's more flexible computer tools, shipbuilding companies should soon be able to take a major step forward with their CAMS (refer to the SP-4 Software Tools Report). One shipyard has just completed a very major revision of their management system and organizational procedures with the limited involvement of an outside consulting firm (Shipyard K, Appendix C) and most others surveyed are planning or in the process of upgrading their systems.

There are some particular CAMS areas that shipbuilding companies have not utilized. Computer assisted time standards generation system is a new application at two shiyards, primarily for their sheet metal shops, and with a very high rating, 8, it is possible that others will follow. Facilities planning and plant layout are complex issues but have largely been treated simplistically, especially by shipyards with a great deal of space available. As pre-election outfitting methods increase the systemization of facilities, layout should also increase. Economic evaluation is a very involved process at most shipyards; however, most projects and/or improvements are creatively justified, without post-implementation audit or in-process monitoring. This failing is not unique to shipbuilding but is true of most U.S. manufacturing companies.

The largest problem with most of the CAMS is their total lack of cost estimating and "true" scheduling ability. Most cost estimates are arrived at in a totally manual mode, relying heavily on planners' past experience and top management's review of specifications. In a slow economy the number of major estimates required is low, and most repairs and/or overhauls can be handled by guestimation. However, using a computer assisted estimating system would greatly improve speed, accuracy, and flexibility (what if type sensitivity analysis) and prepare a shipyard for a more brisk economy. Also, most scheduling systems are more a status and control system then a schedule-making system. Again, scheduling personnel arrive at a schedule manually and they input it into a computer system, which then monitors schedule completion and generates certain reports. A true scheduling system would take work package information and real shipyard constraints, such as material ready dates, facility capacities, and due dates, and creates achievable schedules. Such systems[3] exist today and are called finite capacity scheduling systems. The incorporation of pre-erection Outfitting planning techniques (or work packaging techniques) and up-front scheduling tools can greatly improve the burdensome task of scheduling.

3.5 SYSTEMS INTEGRATION

The CAD/CAM Glossary by John J. Allan, III, defines an integrated system as (1) a complete system with all hardware and software elements required to perform specified functions supplied by one producer, (2) a software system were various distinct phases are integrated so that coupling between the program phases is simple to use if not automated entirely. The first definition is more relevant to turnkey systems vendors' marketing appraoch than it is an aid to understanding how systems communicate with each other in the shipbuilding industry. The later definition is useful; however, two further distinctions must be made. First, definition 2 as it reads now applies more to interfaced systems. An integrated system would have the added requirement of having a piece of data stored in only one place (no data redundancies) either in a distributed data base system or in one common data base. The second distinction is that one program can be integrated across several CAD/CAM categories (e.g., SPADES or AUTOKON are integrated across hull definition; fairing and lofting, hydrostatic analysis, and many N/C categories) or several separate programs can be integrated via common (shared, not duplicated) data. The former is described in section 3.3.3, Software/Vendor Evaluation, whereas the latter is of concern here.

Now that integration has been thoroughly defined it is appropriate to conclude that no two systems are integrated at a U.S. shipyard or design agency. The definition of integrated systems used by this survey is vitally important for future measurement of shipyard trends; however, it is sufficiently narrow that few companies in any manufacturing industry could claim to have fully integrated systems. The level of integration is neither good nor bad. While integration is intuitively desirable (i.e., information independence, nonredundancy, relatability, integrity, accessibility, shareability, security, performance, and administration[4]) it is currently a complex undertaking and not necessarily the most efficient and effective approach. However, the degree of integration reflected by shipyards in the future will be an indicator of communication sophistication, information handling flexibility, and direct control over operations. Shipyard K (Appendix C) is approaching an integrated management information system, Shipyard E has long term plans to evolve into a common data base, and Shipyard S feels that a common data base is not the most efficient approach and plans instead to improve computerization by functional area.

While no systems surveyed are truly integrated many are interfaced. Computer Aided design (CAD) is the most interfaced category with "links" from engineering analyses, N/C process control, parts nesting which was defined into the manufacturing technologies category, and some interface from CAD for cutting, programming shell plate development, and tape verification. Most all interfaces are in-house developed links though in the near future some will be vendor supplied such as IGES, the interfacing format for CAD drafting systems (since it is a national standard). Other such standards may be forthcoming but are not readily apparent.

3.6 SUMMARY OF SOFTWARE EVALUATION

This section has attempted to evaluate qualitatively the past performance of the systems currently in use by the U.S. shipbuilding industry from their perspective only. Therefore, this evaluation does not reflect the total worth or usefulness of these systems to other industries. This analysis has the advantage of a large base of contributing evaluators from shipyards and design agencies, which have individually determined the value of what they are using today. The SP-4 software tools report should be referred to in order to understand what could be used in the future. Therefore, an individual shipyard/ design agency reviewing this section can get an understanding of what the industry trends are and begin to evaluate a specific software package for themselves.

4. COMPUTER TECHNOLOGY BENEFITS AND PROBLEMS

The third major component (Part III) of the CAD/CAM survey questionnaire deals specifically with the benefits and problems associated with the six major computer technology categories. The questionnaire requested qualitative, ratings, per the recommendation of the advisory board, so as not to compromise any proprietary quantitative information. The qualitative ratings are very useful in identifying CAD/CAM technology benefits and problems and ranking their importance.

The survey’s Part III matrix (Appendix B), Computer Technologies Benefits and Problems, allowed each participant three qualitative ratings; a Plus (+), check ([), or a zero (0). For the benefits section, Part IIIA, these ratings represent substantial benefits, some benefits, and no benefits observed, respectively; and similarly for the problems section, Part IIIB, they stand for substantial problems, some problems, and no problems observed. For ranking purposes each plus counts for two points, a check for one point, and a zero for no points. This section will determine overall shipyard and design agency rankings separately and then examine the individual CAD/CAM technology pros and cons for each.

4.1 SHIPYARD CAD/CAM TECHNOLOGY BENEFITS AND PROBLEMS

There are almost twice as many benefits (522) reported as problems (292) in terms of evaluation points and 25 percent more absolute benefits identified (342) than problems (258). These are positive indicators and support two conclusions: (1) there are more benefits associated with CAD/CAM technologies than problems (absolute percentage difference), and (2) the intensity of the benefits is much greater than the severity of the problems (evaluation percentage difference).

Another measurement which is important to get a holistic overview of Benefits and problems is stability. A relative comparison of each technology’s contribution to benefits and problems, Table 17, adds this important third dimension, identifying which technologies are in synchronization. In

TABLE 17. SHIPYARD CAD/CAM DIFFERENTIAL

	% Benefit	% Problem	(B-P)
CAD	16.5	19	-2.5
CAE	12	16	-4
N/C	22	16	5
MT	16.5	20	-3.5
CAMS	26	23	3
AUTO	7	6	1
TOTAL	100%	100%	0
BASE	522 points	292 points	

absolutes, benefits outweight problems in all CAD/CAM categories, but compared to their contribution to the total, some are relatively better than others. Reviewing the difference column in Table 17, positive values mean that the percentage of benefits to total benefits is larger than the percentage of problems to the total problems for a given technology. For example N/C has 6 percent more contribution to overall benefits than to problems, which supports the fact that N/C is an established and reliable technology. Since, the differences between problems and benefits are not large in this comparison it indicates that all technologies are in relative sycronization. In other words, as a shipyard gains experience with a CAD/CAM technology they find roughly twice as many benefits as problems (in intensity). The reason this is so important is that if one CAD/CAM technology was greatly out of sync it would be a possible indicator that it was a boon or a bust for the shipyards. U.S. shipyards, therefore show relative stability with their CAD/CAM applications.

4.1.1 Benefits

Computer assisted management systems (CAMS) have had the greatest benefit in U.S. shipyards of any other CAD/CAM technology, rating 26 percent of the 522 points assigned to benefits (138 points), Figure 31. N/C Process Control is second with 22 percent of the points (116). Manufacturing technologies

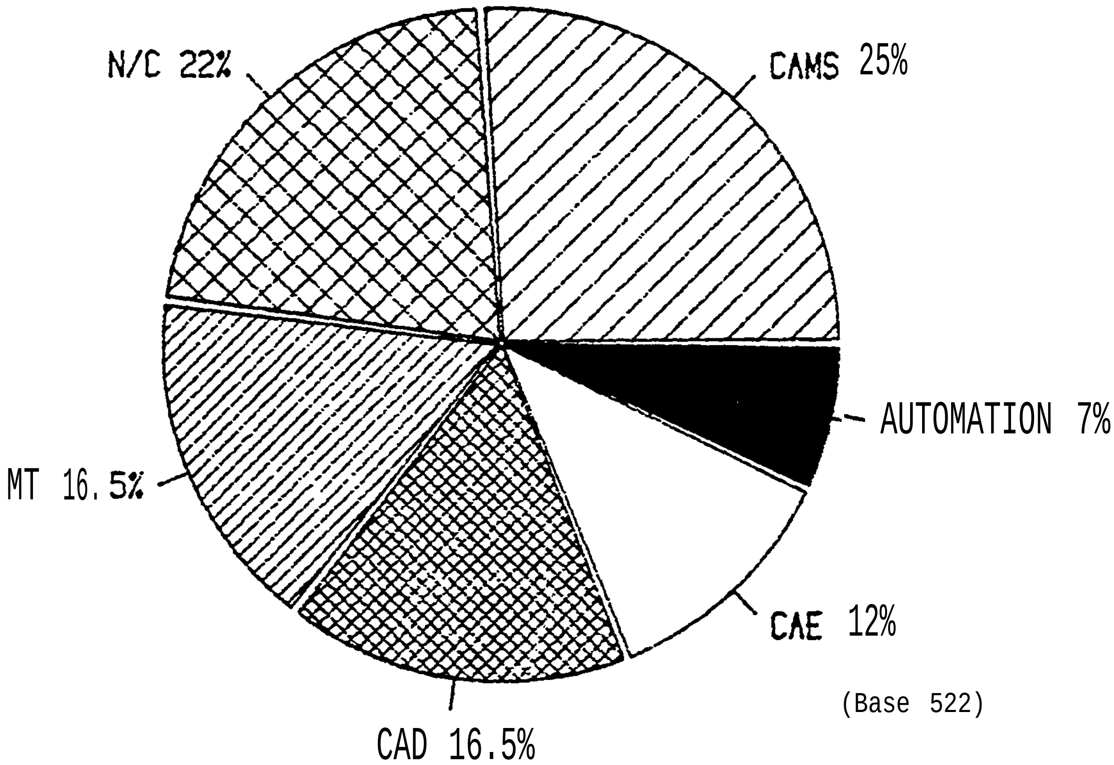


Figure 31. Shipyard CAD/CAM Technologies' Contribution to Benefits

(including lofting and nesting), Computer Aided Design, and Computer Aided Engineering analysis technologies all rank about the same at 16.5 percent, 16.5 percent, and 12 percent, respectively. Automation has 7 percent of the benefit points, however this is somewhat inflated due to the enthusiasm of the three shipyards dabbling with it.

The three top benefits are leadtime reduction, increased product quality and improved control of operations receiving 56, 56 and 51 points, respectively (refer to Figure 32). The next "level" of benefits include greater producibility (42), labor savings (42), increased standardization (41), improved scheduling (39), improved planning (38), and greater flexibility (35). Increased interaction with 27 points stands out as the next level. Integration is primarily referred to as a benefit of management systems and refers to their vertical integration of shipyard functions as opposed to integration with other types of systems. Improved procurement (20), facilities planning (16), and materials handling (13) represent the lowest tier of benefits since safety is only a marginal concern (8 points) with most CAD/CAM

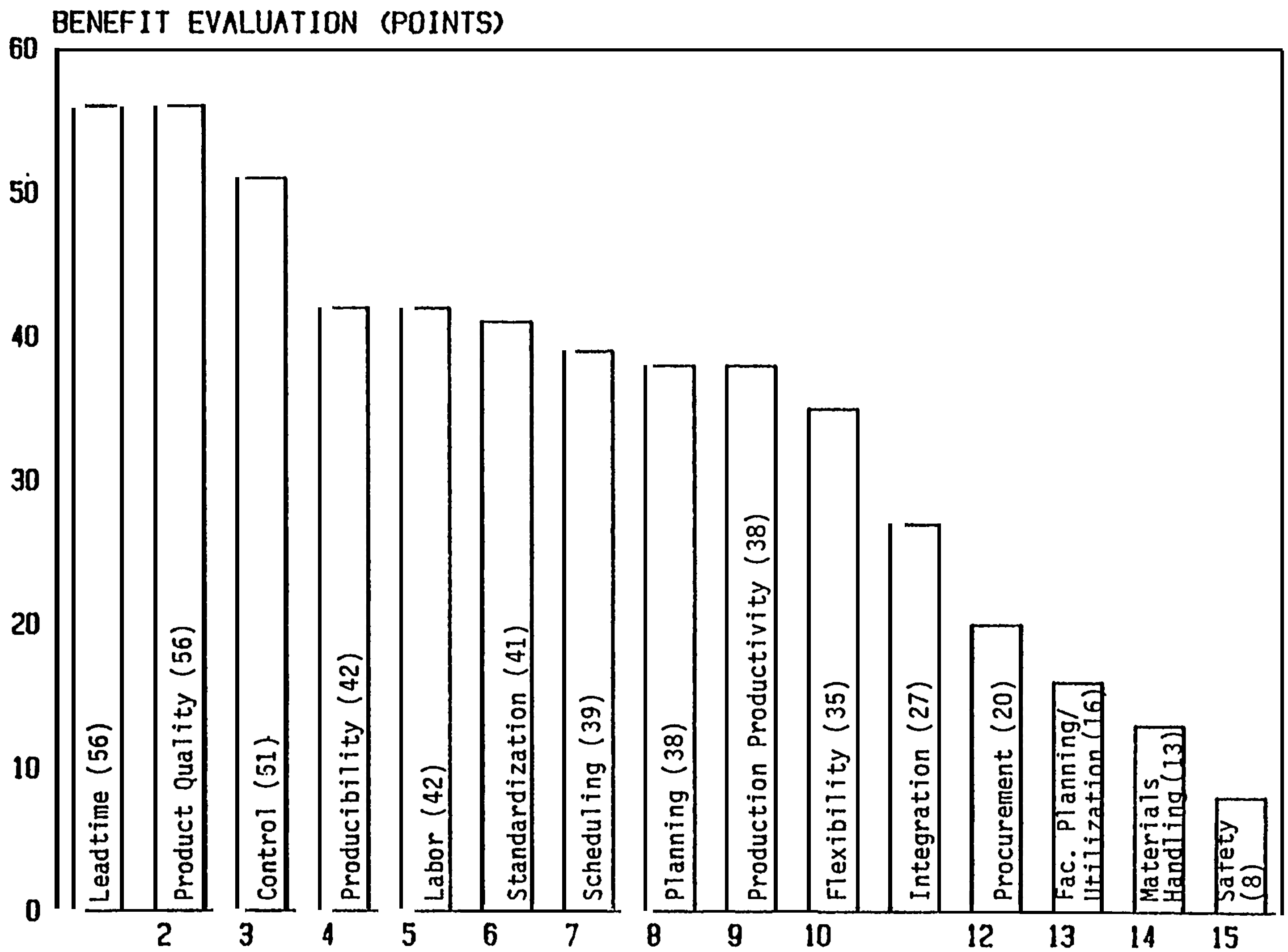


Figure 32. Shipyard CAD/CAM Technology Benefits

technologies, except those including automated equipment (NC, MT, and automation). This is usually of more concern on an application (vs technology) basis. Note: this does not de-emphasize the importance of shipyards' efforts to improve safety, it simply indicates that most participants do not envision currently applied CAD/CAM technologies as important contributors to safety.

The top three benefits (leadtime, product quality and control) best characterize the thrust shipyards have had for applying CAD/CAM technologies; however, this partially challenges the traditional cost justification procedures, which are usually measured in labor savings potential. Labor savings is important, ranking fifth (tie for fourth, actually), but the qualitative emphasis in other directions tends to suggest a greater need to count intangible costs more heavily in cost/benefit analysis and project justification than in the past.

Each CAD/CAM technology can be viewed from two perspectives. Referring to Figure 33, the Benefits Map, a CAD/CAM technology can be traced through its overall benefits profile or each benefit can be reviewed for its composition in terms of CAD/CAM systems. This is done immediately for the overall top benefits (section' 4.l.l.1) and later, CAD/CAM technolgoies are each reviewed for their strong and weak areas together (Sections 4.1.3-4.1.9).

4.1.1.1 Leadtime, Product Quality, and Control

Leadtime. Leadtime is reduced primarily as a result of applying CAE analysis technologies (refer to Figure 33) with CAD and N/C and manufacturing technologies also contributing greatly. CAE contributes to fast feasibility analysis and is also useful on evaluation of change requests. CAD technologies allow for both engineering analysis and drafting productivity improvement as well as faster processing of changes. N/C and manufacturing technologies contribute to production speed and flexibility. Management systems currently have only marginal effect on leadtime reduction primarily due to their lack of use in estimating and/or initial planning.

Product Quality. Product quality is improved by the reliability and repeatability of N/C process control and by the tandem efficiency and increased-sensitivity analysis afforded via CAE and CAD technologies. Manufacturing technologies contribute primarily through applications which support N/C and the sheet metal shop (to some extent). Management systems contribute

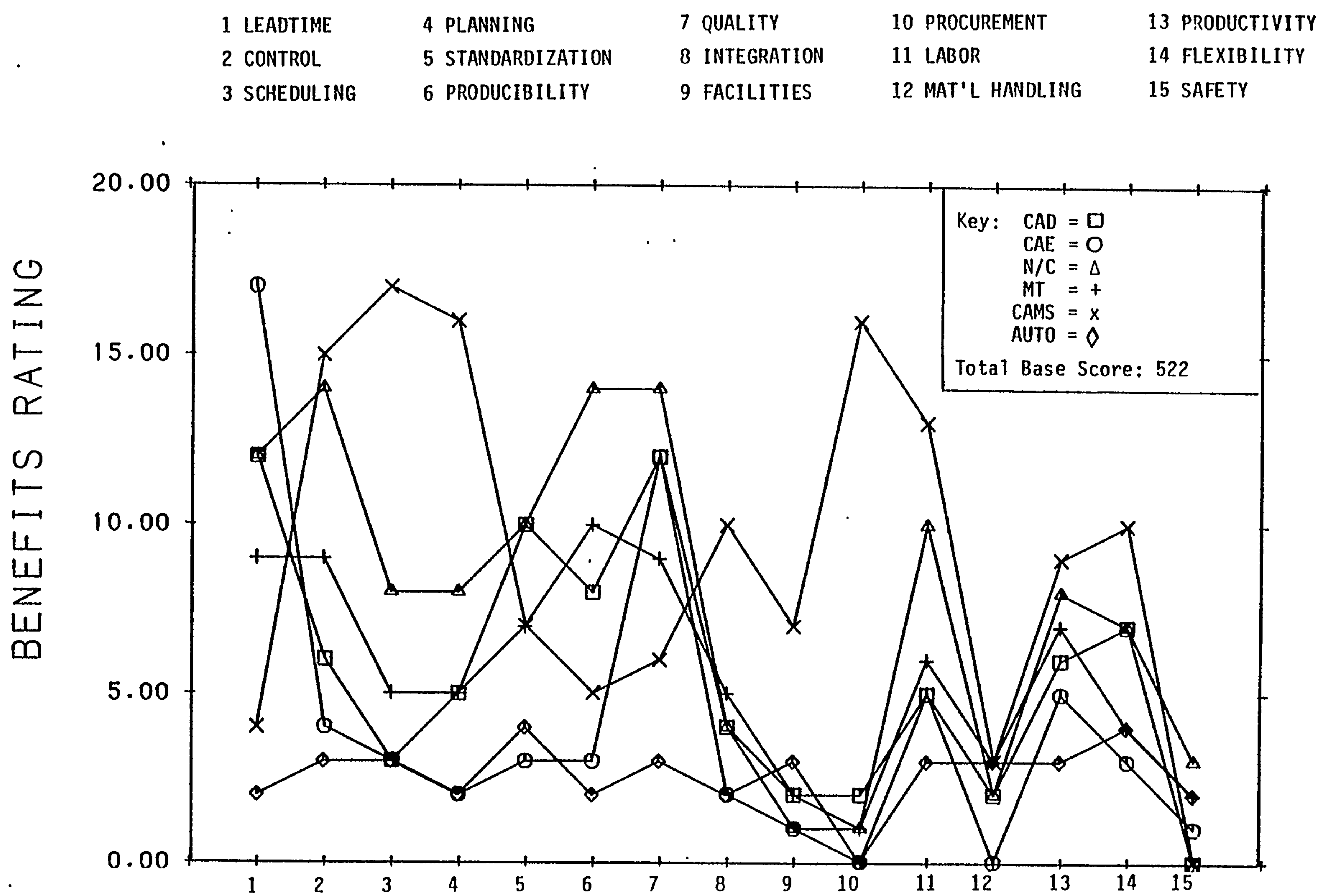


Figure 33. Shipyard CAD/CAM Benefits Map

indirectly since increased control and better organization lead to decreased rework and/or material errors.

Control. Control was viewed from two different perspectives in the benefits evaluation. Control of shipyard operations, the broader definition of control, is evidenced by the high rank of management systems. Process control, the more specific definition of control, benefits via N/C. Control, in the broad sense, is an aspect of most other benefits listed, providing a more significant impact than even the ranking suggests. The high ranking of management systems overall (26 percent of all benefits points), Figure 31, and the correlation between number of management systems and overall shipyard applications (four of the top five) in Section 2.3.3.5 lend additional support to this observation. N/C process control with 22 percent of the benefit points also suggests that even the specific definition of control is important.

This same type of analysis can be determined for the other 12 benefits as well, following the same reasoning.

4.1.2 Problems

Computer assisted management systems (mostly in-house developed) have the highest problem rating, 23 percent (68 points), followed closely by manufacturing technology, 20 percent (59 points), and computer aided design technology, 19 percent (55 points), Figure 34. N/C and CAE analysis technologies have 16 percent of the total problem points assigned (47) and automation has 6 percent (16).

About four levels of intensity can be assigned to the CAD/CAM technology problems in Figure 35. Integration stands as the largest problem or the first level with 41 points. The next level goes from software maintenance/support (35) to training (29). The third level goes from system user friendliness (25) to user acceptance (18). And finally the fewest problems were associated with hardware maintenance/support (15) and information integrity (15) and retrieval (11). It is certainly impressive that information integrity is not a problem when integration is such a major problem; this may well reflect a great deal of effort on the part of the shipyards to keep systems up to date manually.

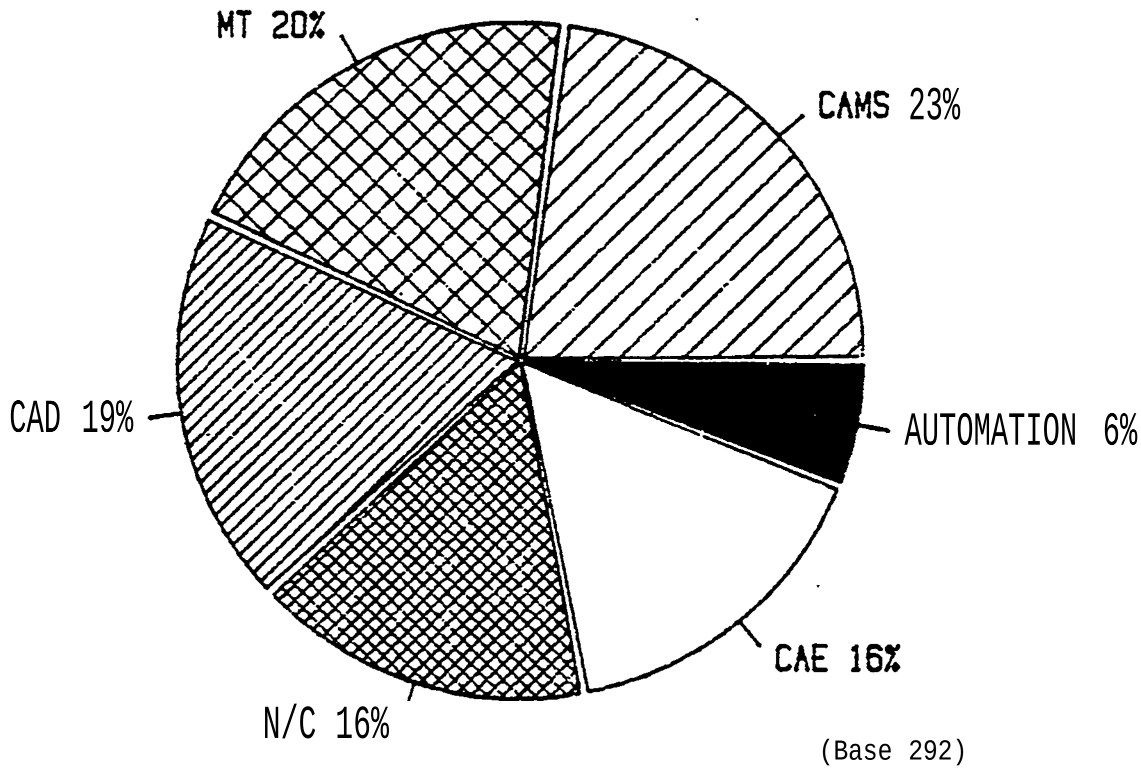


Figure 34. Shipyard CAD/CAM Technologies' Contribution to Problems

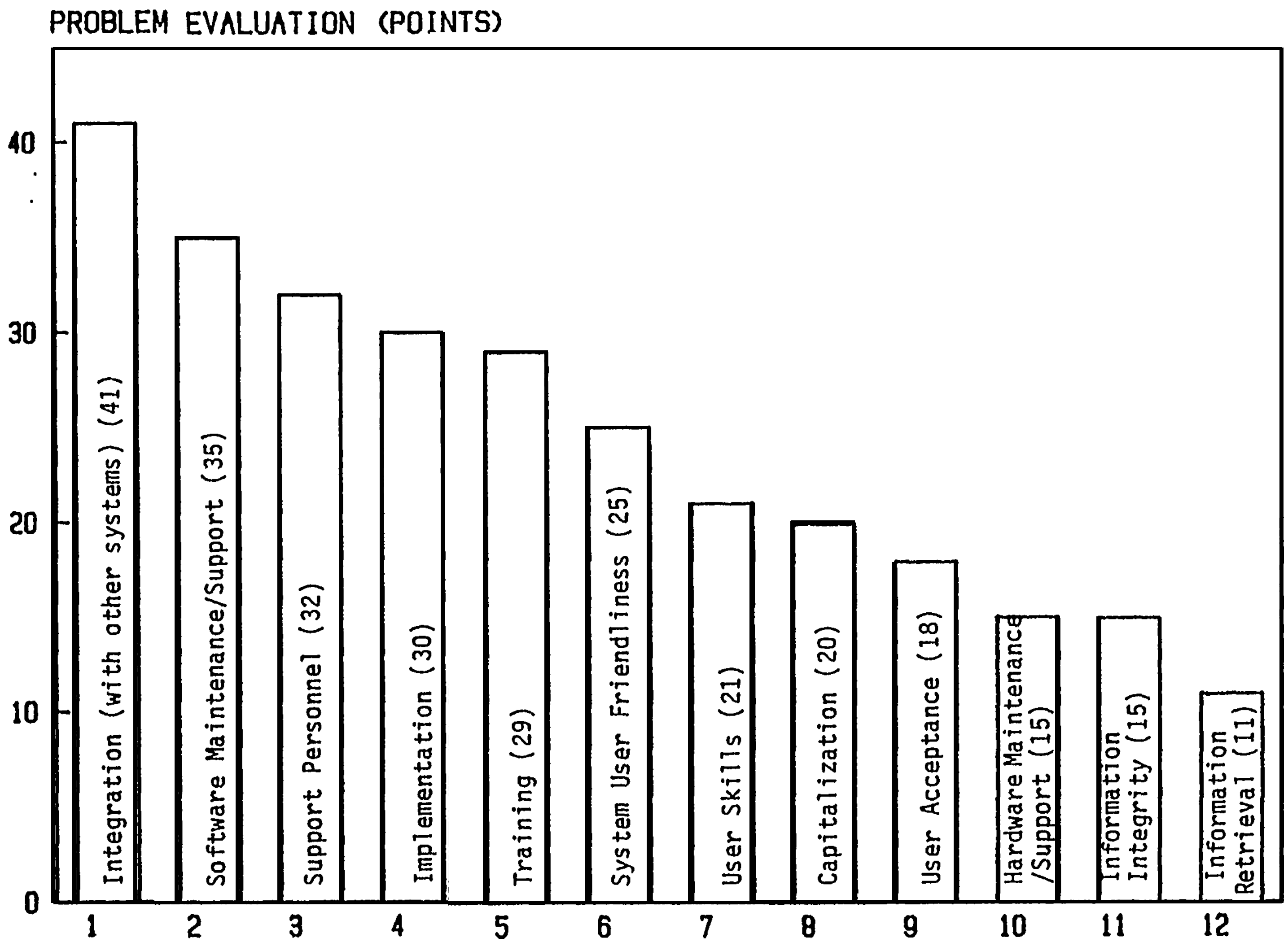


Figure 35. Shipyard CAD/CAM Technology Problems

Once again, traditional methods are challenged: Labor savings as the basis of cost justification before (Section 4.1.2.1) and capitalization as a major barrier, here. Capitalization is important but is 8th in the list of twelve problems (Figure 35). In this case, however, instead of liberalization of traditional procedures, it serves more as a warning that there may well be more serious implications in a piece of software (or hardware) than immediate affordability and they should be considered, even contractually, before buying a CAD/CAM technology.

4.1.2.1 Integration

Integration is the worst problem and encompasses virtually all of the CAD/CAM technologies with roughly equal intensity (except automation). The problems map, Figure 35, shows that management systems are the largest contributor, possibly due to the company-wide reach (large scope) they try to achieve. Following closely behind is CAD, still an isolated drafting tool or front-end to engineering and N/C software packages. Then comes CAE analysis packages, which do not tie with each other or CAD drafting sytems. Finally manufacturing technologies and N/C process control are not integrated to many shipyard’s satisfaction. This across-the-board dissatisfaction with CAD/CAM technology integration indicates that shipyards have applied “islands of technology" or stand-alone systems to their operations but not by choice. They would like to at least be able to interface them.

Notice also that the other top four problems: software maintenance, support personnel, implementation, and training all have input from each CAD/CAM technology. Even though each has a slightly different mix, it is a good indication that these four problems are common to most CAD/CAM technologies and should be reviewed before purchase or implementation.

4.1.3 Specific CAD/CAM Technology Benefits and Problems

The objective of this section is to provide a closer look at the strong and weak points within each CAD/CAM technology category. Reference to the Benefits and Problems Map (Figures 33 and 36) are useful in addition to the tables within each subsection. Table 18 lists the top five benefits and problems associated with each major CAD/CAM technology category.

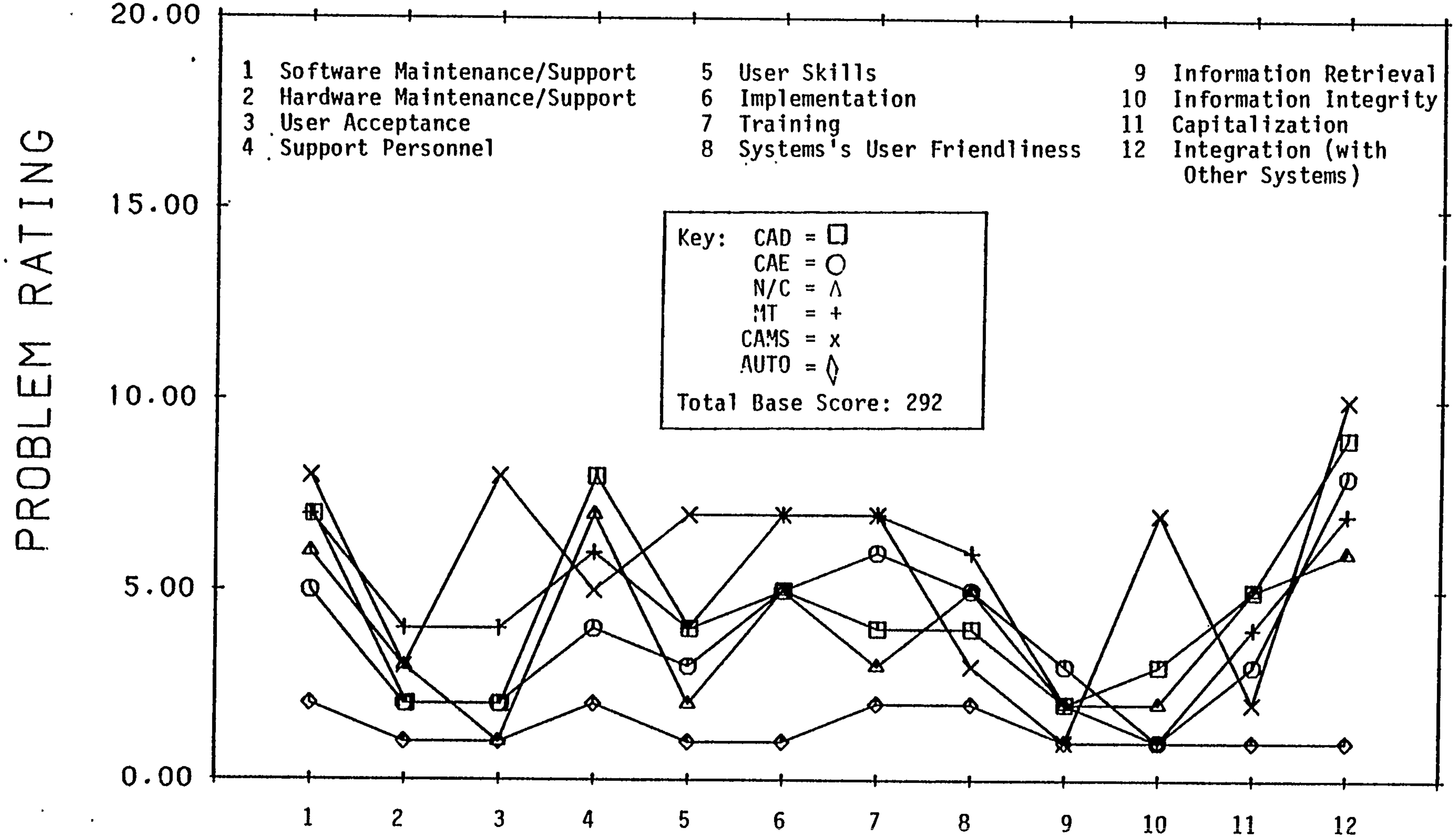


Figure 36. Shipyard CAD/CAM Problems Map

TABLE 18. TOP RANKED SHIPYARD BENEFITS AND PROBLEMS FOR SPECIFIC CAD/CAM TECHNOLOGIES

Benefits	Problems
CAD Technologies:	
1. Leadtime (12	1. Integration (9)
2. Product Quality (12)	2. Support Personnel (8)
3. Standardization (10)	3. Software Maintenance/Support (7)
4. Producibility (8)	4. Implementation (5)
5. Flexibility (7)	5. Capitalization (5)
CAE Analysis Technologies:	
1. Leadtime (17)	1. Integration (8)
2. Product Quality (12)	2. Training (6)
3. Production Productivity (5)	3. Software M/S (5)
4. Labor (5)	4. Implementation (5)
5. Control (4)	5. System User Friendlines 5)
N/C Process Control Technologies:	
1. Product Quality (14)	1. Support Personnel (7)
2. Control (14)	2. Integration (6)
3. Producibility (14)	3. Software M/S (6)
4. Leadtime (12)	4. Implementation (5)
5. Labor (10)	5. System User Friendliness.(5)
Manufacturing Technologies:	
1. Producibility (10)	1. Integration (7)
2. Leadtime (9)	2. Software M/S (7)
3. Product Quality (9)	3. Implementation (7)
4. Control (9)	4. Training (7)
Computer Assited Management Systems:	
1. Scheduling (17)	1. Integration (10)
2. Planning (16)	2. Software M/S (8)
3. Procurement (16)	3. User Acceptance (8)
4. Control (15)	4. Implementation (7)
5. Labor (13)	5. Training (7)
6. Flexibility (l0)	6. User Skills (7)
7. Integration (10)	7. Information Integrity (7)
Automation	
1. Standardization	1. Software M/S (2)
2. Flexibility (4)	2. Support Personnel (2)
	3. Implementation (2)
	4. Training (2)

4.1.3.1. Computer Aided Design

For computer aided design, the top ranking benefits are leadtime, product quality, standardization, producibility, and flexibility. The primary disadvantages or problem areas of computer aided design are integration with other systems, support personnel, software maintenance and support, implementation, and capitalization. Both the advantages and disadvantages are somewhat predictable based on Section 3, Software Evaluation, and in this case Part III of the survey questionnaire supports the advantages and disadvantages of computer aided design established in the other two parts.

4.1.3.2 Computer Aided Engineering Analysis

Computer aided engineering analysis (CAE) main benefits are Ieadtime and product quality. Since engineering analysis is very tedious and involves routine mathematical calculation/simulation, computerization reduces the leadtime required to analyze a product and also reduces the error involved in manual calculation; hence, improving the product quality. The biggest problems facing CAE are integration, training, software maintenance and support, implementation , and system user friendliness. There are no unique-aspects to these problems. Almost all stand-alone software has these problems.

4.1.3.3 NC Process Control

Numerically controlled machinery is the oldest form of automation available to the shop floor. It has been broken out into a separate section so that it would not bias the other two categories of manufacturing technologies and automation, since it is expected to be the most widely implemented single technology available to the shop floor in terms of computerization. In fact, with 116 benefit points reported by 18 shipyards, it appears to be the most proven computer technology other than computer assisted management systems. The strong benefit areas for N/C process control were product quality, control, producibility, leadtime, and labor.

Even though there were very favorable benefits observed, there are only a few shipyards-applying it outside of steel plate cutting, but those that do find it very beneficial. The major problem areas were support personnel, integration software maintenance/support, implementation, and system user-friendliness. In the IIT Research Institute study entitled “Why More NC is

Not Being Incorporated," it was found that the two primary barriers to numerical control were that there was a great lack of hands-on experience on the part of industry and, subsequently, cost justification. Shipyards have the added barrier of procuring many of its machined parts, N/C's primary strong application area, and therefore do not require N/C as much as industry.

4.1.3.4 Manufacturing Technologies

There are slightly fewer benefits observed in the manufacturing technologies category than in N/C process control, however there was still a good positive response in this category. The primary benefit areas were producibility, leadtime, product quality, and control. Other than computer-assisted management systems, manufacturing technologies have the highest number of reported problems. These problems were not enough to offset the benefits listed. Some of the shipyards are applying computer aided time standard generation and process planning in addition to lofting and nesting (the most common applications), which account for some of the problems and benefits observed. Some of the primary problems were integration, software maintenance/support, implementation, and training.

4.1.3.5 Computer Assisted Management Systems (CAMS)

CAMSs primary benefits are scheduling, planning, procurement, control, labor, flexibility, and integration Since most of these systems are in-house developed and maintained they are continually being upgraded and expanded (refer to Section 3.3.2, In-house programs); however, most still lack the sophistication to assist with initial planning and estimating. Therefore, scheduling and planning benfits primarily refer to schedule detail generation and schedule monitoring, which are very important and otherwise tedious tasks at a shipyard. Integration as a benefit refers to the broad scope of CAMSs to track and assit several different departments through one system (vertically integrated).

The primary problems associated with CAMSs are integration with other systems (e.g., CAD, CAE), software maintenance and support, user acceptance, implementation, training, user skills, and information integrity. Observation suggests that with the current trends in CAMSs at the U.S. shipyards, the problem of integrating with other systems will be greatly reduced over the next five years especially with the use of new, sophisticated software tools (refer to the SP-4 Software Tools report). The fact that current CAMSs are not presently integrated horizontally (with other systems) accounts, at least partially, for the problem of information integrity. Other factors include redundant data files and post-facto (non-real time) work tracking systems. However, a great deal of credit should go to the software designers because there is very little complaint about system user friendliness (3) or information retrieval (1).

It is unclear why capitalization is not considered a problem for CAMSs when it most likely is the most costly CAD/CAM technology in use (in terms of development and maintenance) covering basically overhead functions of an enterprise. Meanwhile, on the shop floor most computer technologies need cost justification based on labor savings. Certainly some of this is explained by the reporting requirements, specified by the government, that are necessary simply to do business, but this is not the only reason.

4.1.3.6 Automation.

Automation application in U.S. shipyards is at the very beginning stages of the learning curve and does not merit further analysis at this time. In five years this may be an area with more planned future implementations.

4.1.4 Other Shipyard CAD/CAM Benefits and Problems

There were two comments, both problems, in the survey questionnaire Part III Section C, Other Benefits/Problems. The first concern was the interchange of graphics between different CAD systems. Hopefully, the Initial Graphics Exchange Specification (IGES) version 2.0[5] is addressing this need between CAD drafting systems. It primarily depends on CAD drafting system vendor's participation and customer demands to result in IGES 2.0 compatible systems. U.S. shipyards have one additional problem in that a great deal of their CAD technology is a part of engineering analysis and N/C and lofting software such as SPADES, AUTOKON, HULDEF, etc. For IGES to be useful to a shipyard these other programs with CAD graphics front-ends will need to be IGES compatible also, which may be difficult to persuade the vendors to do.

The second concern was the "yard-wide fear and mistrust of computer applications because of lack of understanding and knowledge." This is a-legitimate concern that appears in many different symptoms within the shipyard as evidenced by the shipyard visit summaries (Appendix C). Careful pre-planning and user involvement and training are usually easier said than accomplished. For more in-depth clues to alleviation of this problem turn to Section 5.1., U.S. Shipbuilding's Successful Approaches, and the SP-4 Software Tools project implementation senarios.

4.2 DESIGN AGENCY CAD/CAM TECHNOLOGY BENEFITS AND PROBLEMS

There are 20 precent more problems (65) then benefits (53) in terms of evaluation points and 33 percent more problems identified (57) then benefits (38). Although this implies that the benefits identified are more satisfactory (evaluation percentage difference) than the problems that are unsatisfacotry (absolute percentage difference), it has to be regarded as a negative indicator since problems outweight benefits.

Stability, as described in section 4.1, is also affected such that the three CAD/CAM technologies in use by design agencies (CAD, CAE, and CAMS) are out of synchronization, Table 19. CAD technology is the only category where benefits (26) outweigh problems (24). This has the affect of providing a large positive differential (12, Table 19) in CAD technolgy's favor, thus a positive indicator for CAD and resulting in negative differentials for CAE analysis (-8) and computer assisted management systems (-4). What this implies is that design agencies feel that they have had more success implementing CAD than other computer aids and that CAE packages have produced more problems (relative to benefits).

Design agencies are much newer to CAD/CAM technology application than shipyards and have fewer resources (but also fewer needs) to invest in them. These negative indicators, thus far, may well imply that they are much farther back on the learning curve than most shipyards (instead of worse at implementing them). If this is true (and observation as well as age of software indicate that it is), then it is understandable to realize more problems than. benefits early on. Computer software, like most other new technology begins with a period of adjustment where the new users will find more problems than benefits. Once the organization has time to change and to catch up to the new technology, the advantages will become more readily apparent (or the technology is removed). Design agencies, based on planned future implementations

(Section 2.2.2), fully expect the benefits and are expanding their application of CAD/CAM technologies. Therefore, design agencies are optimistic (or just realistic) that the benefits to be derived from CAD/CAM will outweight problems.

TABLE 19. **Design Agency CAD/CAM Differential**

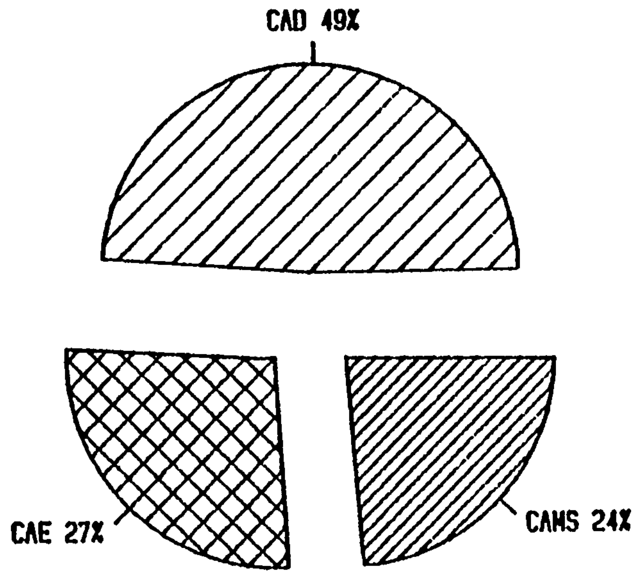
	% Benefits	% Problems	% Benefits - % Problems
CAD :	49	37	12
CAE :	27	35	- 8
CAMS :	24	28	- 4
Total	100%	100%	0
Base	53 points	65 points	

4.2.1 Benefits and Problems

Computer aided design technology contributes the largest share of benefits with 49 percent of the evaluation points (26), Figure 37. Computer aided engineering analysis tools show 27 percent (14 points) and CAMSs show 24 percent (13 points). CAE programs have been in use longer than CAD technologies (mostly CAD drafting systems), three versus 10 years average; however, CAD has quickly taken over as the most beneficial computer application. This follows logically since a design agency's primary product is concepted and preliminary designs and design/drafting services, therefore represent a large potential benefit via computerized drafting.

Most problems are evaluated to be in computer aided deisgn, 37 percent (24 points), followed closely by CAE at 35 percent (23), as shown in Figure 38. Computer assisted management was evaluated at 28 percent (18) of the problems. Both benefits and problems for CAMSs are unintentionally inflated. There are only five applications (Section 2.3.5) compared to 36 CAE and 23 CAD applications and the type of CAMS applications are not very elaborate. The high number of problems with CAE is due in large part to their average age, 10 years, implying that they may well be in need of updating. Also, many programs developed in the early 1970s, especially engineering ones, were batch operations with very few interactive features.

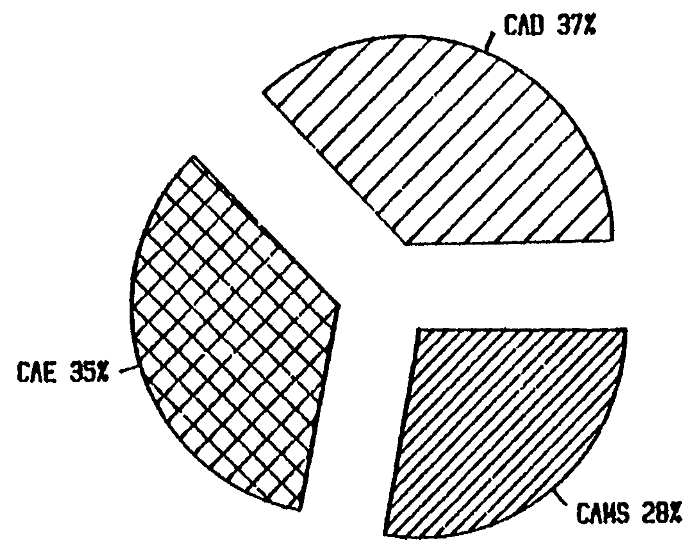
FIGURE DG.



(Base 53)

Figure 37. Design Agency Technologies' Contribution

FIGURE DH.



(Base 65)

Figure 38. Design Agency CAD/CAM Technologies' Contribution to Problems

The specific benefits and problems that design agencies found with CAD/CAM technologies are summaried in Table 20. Product quality, producibility, and production productivity were attributed to both CAD and CAE systems and standardization just to CAD, Figure 39. CAMSs major attribute is scheduling. Production productivity to a design agency primarily refers to drawing/design release schedules and in that sense is comparable to leadtime by a shipyard's definition. Given that, leadtime is in the top five benefits for a design agency, though not as significant as in the shipyard.

Integration with other systems, software maintenance and support, and system user friendliness are the primary CAD/CAM prolems identified by design agencies; CAD, CAE, and CAMS technologies all share roughly equal responsibility for this low rating, Figure 40, further supporting at least the top two problems as universal. Implementation problems also seem to be in the top five main problems of both design agencies and shipyards. Problems in implementation should be reduced as shipbuilding firms progress further through the learning curve of applying CAD/CAM technology, provided that the organizational structure adapts to technological change. Understanding the strengths and weaknesses associated with the implementation of CAD/CAM technologies should greatly assist in planning for implementation in the future.

4.2.2. Specific CAD/CAM Technology Benefits and Problems

Table 21 identifies the strengths and weaknesses of each individual CAD/CAM technology category per the expereince of participating design agencies. Many of these attributes are common to the major software categories in general and a simple comparison with Table 18 (Shipyard Experiences) lend a clue to which ones these are. Instead of reiterating much of the material in section 4.1.3.1 (CAD), 4.1.3.2 (CAE), and 4.1.3.5 (CAMS), the following paragraphs will discuss the differences between shipyard and design agency observations.

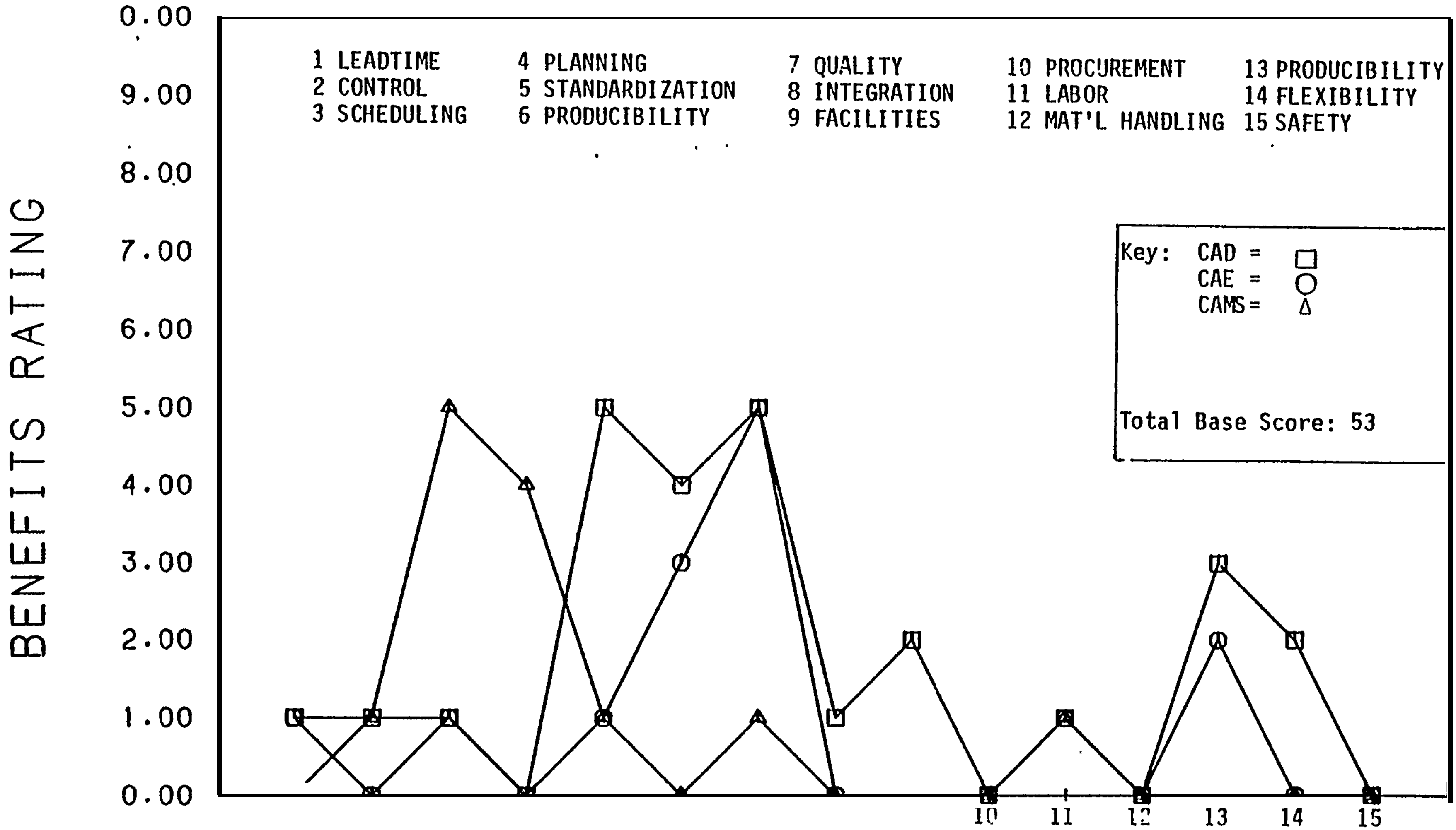


Figure 39. Design Agency CAD/CAM Benefits Map

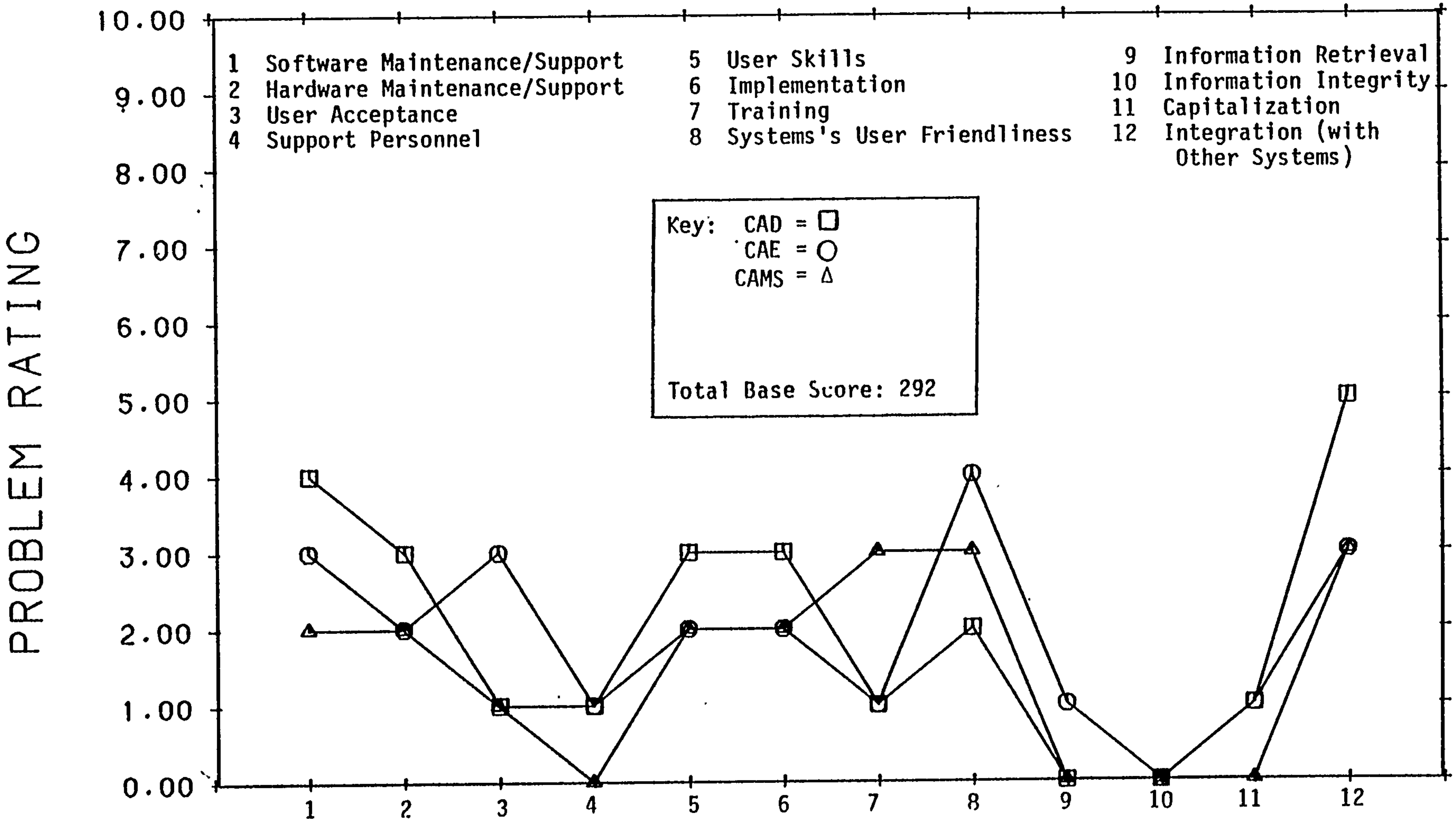


Figure 40. Design Agency CAD/CAM Problems Map

TABLE 20. DESIGN AGENCY CAD/CAM TECHNOLOGY BENEFITS AND PROBLEMS

BENEFITS		PROBLEMS	
Name	Rating	Name	Rating
1. Product Quality	11	1. Integration	11
2. Producibility	7	2. Software Maintenance	9
3. Standardization	7	3. Systems User Friendliness	9
4. Scheduling	7	4. User Skills	7
5. Production Productivity	5	5. Implementation	7
6. Planning	4	6. Hardware Maintenance	7
7. Labor	3	7. User Acceptance	5
8. Control	2	8. Training	5
9. Leadtime	2	9. Support Personnel	2
10. Flexibility	2	10. Capitalization	2
11. Facilities Planning/Util.	2	11. Information Retrieval	1
12. Integration	1		

4.2.2.1 CAD

All of the design agency observed CAD technology benefits are similar to the ones observed by shipyards, Tabel 21. Shipyards observe one added benefit, flexibility, which is more relevant to the production environment (e.g., processing of change orders) than to the conceptual and preliminary design environment. Shipyards observe more difficulty in finding support personnel and funding (capitalization), whereas design agencies found user skills and hardware maintenance more of a problem. This is not suggesting, for example, that a design agency has more available funds to buy a CAD system than a shipyard, rather, it simply implies that a design agency does not perceive funding to be as much of a barrier as a shipyard does. The appearance of both support personnel and user skills as a problem agree with the overall industry trends indicating a shortage of trained professionals in CAD technologies.

4.2.2.2 CAE

Computer Aided engineering analysis programs match up well emphasizing product quality improvement, producibility, and leadtime (shipyard)/production productivity (design agency) in both environments. In fact, the problems are almost identical since implementation problems and user acceptance difficulties represent two aspects of the same problem. Technical and human factors problems arrive out of a resistance to change due to both lack of understanding and threat to organizational security.

TABLE 21. TOP RANKED DESIGN AGENCY BENEFITS AND PROBLEMS FOR SPECIFIC CAD/CAM/TECHNOLOGIES

Benefits	Problems
Computer Adied Design:	
1. Product Quality (5)	1. Integration with other systems (5)
2. Standardization (5)	2. Software Maintenance/Support (4)
3. Producibility (4)	3. User Skills (3)
4. Production Productivity (3)	4. Implementation (3)
	5. Hardware Maintenance/Support (3)
Computer Aided Engineering Analysis:	
1. Product Quality (5)	1. System's User Friendliness (4)
2. Producibility (3)	2. Integration with other systems (3)
3. Production Productivity (2)	3. Software Maintenance/Support (3)
	4. User Acceptance (3)
Computer Assisted Management Systems:	
1. Scheduling (5)	1. Integration with other systems (3)
2. Planning (4)	2. Systems's User Friendliness (3)
	3. Training (3)

4.2.2.3 CAMS

The whole focus of computer assisted management systems is different for design agencies and shipyards. Most design agencies have a modifed cost accounting systems which allow them to obtain the current status of a project via cost and labor hours spent. Otherwise control over progress is evaluated by the contract/project manager without formal computer tracking. This can be done satisfactorily over small teams of workers; however, shipyards have a much larger scheduling and control need due to the complexity and number of tasks involved. Even so, most shipyards treat their design and drafting departments in much the same informal manner as the design agencies. At any rate, major benefits and problems that design agencies are observing (Table 21) are certainly an important subset of the shipyard observations (Table 18).

5. RECOMMENDATIONS AND CONCLUSIONS

It is important to understand how the shipbuilding industry is achieving CAD/CAM technology implementation, as well as what is being done. What is not being addressed is also important in order to establish recommendations for future action. The previous sections identify the state-of-CAD/CAM application in the U.S. shipbuilding industry but do not focus on how (approach, method) they evolved nor what is not yet being implemented (voids). Phase 2 of the CAD/CAM survey involved visits to eight shipyards and one design agency to answer the questions of how. These are highlighted in section 5.1. Voids are identified from the questionnaire results and are expanded upon by the added insight provided by the visits in section 5.2, U.S. Shipbuilding CAD/CAM Technology Voids. Finally some observations on future expectations and recommendations are presented in section 5.3 and general conclusions in section 5.4.

5.1 U.S. SHIPBUILDING'S SUCCESSFUL APPROACHES

This section examines how the U.S. shipbuilding industry is applying CAD/CAM technologies by examining the most successful approaches to implementation. The eight shipyards and one design agency visited in Phase 2 of the survey were selected for their perceived strengths in CAD/CAM applications based upon a preliminary review of the questionnaire results and the endorsement of the advisory board. Each visit is summarized individually in Appendix C and highlighted in this section to establish effective approaches to CAD/CAM implementation.

There are two aspects important to the proper implementation of new technology: management approach and technical approach. Of primary importance is the management of technology, so it is reviewed first; however, behind good management methods need to reside an efficacious technical base, which is reviewed subsequently. Table 22 lists the successful management approaches observed during the shipyard/design agency visits. Each strategic issue merits further discussion. Tactical issues however are aspects of the strategic issues, expressions or plans of action to carry them out, and are therefore discussed in conjunction with the strategic approaches.

TABLE 22. **Successful Management Approaches**

Strategic Considerations

- Upper Management Support
- Production-oriented (real world) Planning Staff
- Planning & Production Staff Cooperation
- Organizational Restructuring to Accommodate New Methods
- Management - Worker/Union Participation in Work Methods Restructuring

Tactical and Implementation Considerations

- Structured Approach to Change
- Incorporation of Outfit Planning Methods
- Outside Programming Assistance for In-House Systems
- Separate Systems Analysis and Programming Functions
- Technical Data Center Approach
- Three-year Payback on CAD/CAM Technology
- Conservative Planned Approach to Computerization
- Employee Participation in Automating Equipment
- Designers and Engineers Working Together

Upper management support is often sited as the most important aspect to implementing any new technology and shipyard visits proved no exception. In addition to confirming the concept, shipyards were quick to expand on the ways upper management has, and should, support modernization. More is required than just consent via capital/budgetary commitment and word-of-mouth: the more directly involved upper management is in the changes, the smoother and quicker the transition. Direct involvement not only communicates a strong support for the implementation, it often results in the needed incentives and organization change(s) (or streamlining) which provide the best possible environment for a new technology to work. In reviewing the summaries in Appendix C it is quite clear to see the contrast between problems involved with superficial upper management support (e.g. lack of middle management incentives to change, empire building, unorganized implementations) and the success of direct upper management involvement (e.g. structured approach to change, middle management support, reorganization, faster implementation of new methods). Most of the shipyard visits involved discussion with middle and upper-middle managers and their staff: however, most expressed the positive effects of their upper management's involvement and many had the results to support their case.

The importance of proper planning is emphasized in the negative effects observed in its absences and the strong positive affects when present. An integral part of proper planning is effective planning and production department communication and cooperation. One shipyard observes that their planning group probably tries to schedule too much detail without the input of production. The result is worse than an inacurrate schedule, it is production's mistrust and disrespect for the planning departments efforts (and vice versa) which results in the severing of an essential feedback for future scheduling efforts. This problem was observed in several shipyards, and resolved in only one (for certain, some others seemed neutral on the subject). One shipyard's approach was to take experienced production personnel and put them in key planning positions meanwhile transitioning a totally new management system with an outfit production orientation. Their long run success is not certain due to the multitude of changes, however intial efforts are positive and upper management is directly involved. Another problem, which needs to be worked out after the human factors issues, is the fact that computer assisted management systems are weak in initial planning and scheduling.

New technologies and more importantly the implementation of new methods, such as outfit planning, have a direct effect on the organizational structure. This can be handled informally through good communications within the existing organizational structure or by restructuring the organization and incentives. Successful approaches to the latter involve most of the tactical considerations in Table 22. Most of the shipyards visited are incorporating pre-erection outfit planning methods. Two exhibit a strong structured approach to change, one has effectively used outside programming assistance for their in-house designed systems, one is using a separate systems analysis staff to design computer systems with a separate programming function to develop them, and another uses a technical data center approach (vs. using the data processing group) which designs and programs software for their manufacturing and engineering departments. One shipyard allows a three year payback period for CAD/CAM systems and another has structured the use of their CAD drafting systems such that designers and N/C programmers work together for repair work. A few shipyards are taking a very cautious approach to computerization while continuing to improve their manual methods. This makes good sense, because a system or method should work in the manual mode before it is computerized. Then the benefits of computerization should be evaluated because sometimes the method change is much more beneficial then computerization, which may not even be needed. Employee participation seems to be very effective in the few isolated cases observed however, there was no observation of it being a company-wide policy.

The technical approaches are highlighted in Table 23. These are mostly tactical in nature and are best elaborated upon in the context of the individual summaries in Appendix C. Two of the technical highlights not in the summary are discussed here briefly. An energy management system, which controls lights, air conditioning and heating saved one shipyard a large amount of money on energy consumption (they claim up to half a million dollars, though this seems high) in 1982. Also at the same shipyard, a point-of-cost data collection system (PODC) is planned for the near future. A PODC is basically an automated punch clock with some limited programmability, which operates on a bar or magnetic coded card, (e.g., machine operator can punch in at a station and indicate the project(s) he/she is working on and the type of work). This information can be loaded in real-time or periodically into the company's management information and accounting systems or data bases. One shipyard says that it will save an estimated 200 hours per week that is spent correcting bad input (wrong charges). Two other shipyards have also reviewed PODCs for their operations, one of which still questions their usefulness, and the other claims they will install one as soon as current systems become more tolerant of the production environment (e.g., more reliable and durable).

TABLE 23. Successful Technical Approaches

- **Outfit Planning Management Information System**
- **Total Re-design of Computer Assisted Management System**
- Energy Management System
- **190 Computer Terminals Located Throughout** the Shipyard
- Pipe Shop Automation
- Pipe Shop Time Standards Generation
- Sheet Metal Shop Manufacturing Technology Application(s)
- High Level Query and Scheduling Languages
- N/C Shop Control
- Process Planning via N/C Tape Library
- 3-D Solids Modeling (Planned)
- Point of Cost Data Collection System (Planned)

5.2 U.S. SHIPBUILDING CAD/CAM TECHNOLOGY VOIDS

It is important to investigate which functional areas of the U.S. shipbuilding industry-are not being covered by CAD/CAM technologies. Those areas that are considered useful to computerize/automate could then become the focus of government and industry research and development efforts. To analyze these voids or weak areas in the U.S. shipbuilding industry, it is important to look across the 79 functional areas specified in Appendix F and identify which areas are not being covered by any CAD/CAM technology. Table 24, Weak/Void Application Areas, reviews each of the seven major functional areas for weak areas within each.

Areas involving design, engineering and planning functions (categories Al, A2, and B) are all fully represented by CAD/CAM technologies even though each has a few weak areas within them. The more production oriented categories (C through F) are increasingly less covered by CAD/CAM technologies. This trend was-noticed early on in section 2, Computer Technologies and Shipbuilding Functions, in the strong showing of design, engineering, and planning activities and is reinforced in this section due to the weak showing of the production oriented sections. A review of each major functional area follows.

TABLE 24. Weak/Void Application Areas (by Functional Area)

Al. Design Drafting and Engineering	Plus	Check	Minus	New	Future	Total
Specification Sheet Generation	1	1	0	2	3	7
Material Requirements Definition	2	1	0	0	5	8
AZ. Production Engineering and Lofting:						
Process Engineering	0	1	0	1	3	5
B. Planning and Production Control:						
Personnel Scheduling	2	1	0	0	4	7
Outfit Production Control	3	1	0	0	4	8
Outfit Installation Control	3	1	0	0		9
Facilities Planning	3	3	0	0	5	9
Material Flow	2	3		0	3	9
Material Handling	2	2	0	0	4	9
C. Steelwork Production:						
Subassembly	2	4	0	0		6
Structural Unit Assembly	2	4	0	0	0	6
Stockyard & Treatment	1	4	0	0	2	7
Outfit Steelwork	2	5	0	0	0	7
D. Manufacturing and Production Activities:						
Woodworking/Joiner Shop	1	0	0	0	2	3
Blacksmith Shop	1	1	0	0	2	4
Rigging	1	1	0	0	2	4
Maintenance	2	2	0	0	3	7
E. Pre-Erection Outfitting Activities (All Bad):						
Module Building	1	1	0	0	1	3
Unit & Block Storage	1	1	0	0	1	3
Block Assembly	1	2	0	0	0	3
Outfitting	2	2	0	0	0	4

TABLE 24 (Cont.)

F. Ship Construction & Instillation (All Bad):						
Electrical Installation	1	1	0	0	2	4
Steetmetal Installation	2	1	0	0	1	4
Woodwork Installation	1	2	0	0	1	4
Staging and Access	1	0	0	0	4	5
Painting	1	0	0	0	4	5
Construction	1	2	0	0	2	5
Hull Erection & Fairing	1	2	0	0	2	5
Testing	2	1	1	0	1	5

Key: Plus - successful application
Check - satisfactory application
Minus - unsatisfactory
New - new application
Future - planned future implementation
Total - number of applications expected by 1988

5.2.1 Design, Drafting, and Engineering CAD/CAM Technology Voids

The major functional area of design, drafting and engineering is the best covered major functional area in shipbuilding currently (Figure 3 in section 2) and in the future (Figure 2 in section 2) in terms of CAD/CAM technologies. Even so, there are still some weak areas. Two closely related shipbuilding functions are specification sheet generation and material requirements definition. Even though currently there are very few CAD/CAM technologies applied to this area the future shows eight new applications planned. These will primarily involve computer assisted management systems with some integration or interface to computer aided design drafting systems. In addition to the weak areas involved with the shipyard functions are some problems sited earlier regarding the CAD/CAM technologies themselves. These are the lack of integration/interface of CAD drafting systems with engineering-N/C systems and effective bill of materials generation interfaced to CAD drafting systems.

5.2.2 Production Engineering and Lofting CAD/CAM Technology Voids

Production engineering and especially the lofting systems are very well covered currently with some additional plans in the future for upgrade and improvement. Of the seven functions in this category (Appendix F), process engineering is the only real weak function. Computer assisted process planning programs do exist today though they must be considered state-of-the-art even though they are not really new. These packages are primarily set up for manufacturing operations as opposed to assembly and construction operations. In addition they usually require some type of group technology (classification and coding) system to be in place which are also rarely assembly oriented. Certainly shop operations currently have the potential to be covered by computerized process planning. In the future, as pre-erection outfit planning methods become-a greater factor in ship production, more of the assembly functions could be covered by computerized process planning techniques. This does not seem to be an area that will be addressed in the next five years but possibly within the next ten.

5.2.3 Planning and Production Control CAD/CAM Technology Voids

Planning and production control functions are second only to design drafting and engineering in terms of overall CAD/CAM technology applications. However, these applications primarily involve computer assisted management systems application. The most important problems with computer assisted management systems are pointed out in section 3.4.4 and are due to the lack of decision support coverage by these systems. Decision support refers to initial planning and scheduling/estimating assistance. Reviewing the specific functional area deficiencies, personnel scheduling is the weakest followed closely by outfit production and outfit installation control. These outfit categories do not refer to pre-erection outfit planning but the normal on-board outfitting activities that are currently practiced in all shipyards. As management systems become more real-time these outfit activities will become increasingly covered. Table 24 shows nine future implementations expected in these areas. Personnel scheduling will continue to remain a weak area until shipyards are able to schedule right down to the individual person, part of this will not be achievable until computerized processing engineering-is in place. Even then the value of this type of scheduling to the shipyard is uncertain. Three very directly related activities are, facilities planning, material flow determination, and material handling. As shipyards evolve into finite capacity scheduling, computerized process engineering, material requirements planning, and more initial decision support aids these areas will likewise increase in their coverage. The current usefulness of having such systems is limited because the ability to access historical information in the proper formats and/or simulate future information to that level of detail is likewise limited.

5.2.4 Steelwork Production and Manufacturing/Production Activities CAD/CAM Technology Voids

Steelwork production is the best covered production category in terms of CAD/CAM technology applications. The specific areas of weakest computerizations/automation involve subassembly work, structural unit assembly, stockyard and treatment, and outfit steelwork. Application of CAD/CAM technologies to these areas will come primarily through control via computer assisted management systems and secondarily through manufacturing technology applications, such as time standard generation and process planning. Some automation might be expected in the out years as repetitive work becomes categorically more identifiable through the use of pre-erection outfit planning techniques. Manufacturing and production activities or shop activities in general are partially covered currently through numerical control applications and CAMS. The woodworking/joiner shop and blacksmith shop activities could possibly benefit in the future through the use of some N/C applications and definitely through more control via CAMS, however they are not areas primarily conducive to computerization or automation. Likewise rigging is not an area for heavy CAD/CAM application, however it could be benefited by initial planning of hoist and pulling gear via a CAD drafting system and possibly the use of some type of automated splicing and rigging machine. Maintenance, especially preventative maintenance, has a great potential for inclusion in existing CAMS as management systems become more real time and equipment utilization is included in scheduling systems. Then it would make sense to include preventative maintenance schedules against specific machine tools and equipment. This is more of a long-term goal requiring time for CAMS evolution.

5.2.5 Pre-erection Outfit Activities CAD/CAM Technology Voids

Pre-erection outfitting activities are probably the worst covered of any shipyard functional area in terms of CAD/CAM technologies. All six areas are poorly covered however the worst are module building, unit and block storage, block assembly, and outfitting. Pre-erection outfitting techniques are just now working their way into a standard operating procedure at most U.S. shipyards. The implications on the organization structure and standard operating procedures need to be determined before computerization should be attempted. This is one reason why very little future activity in these areas is planned in terms of computerization. A CAD/CAM survey in 1988 should turn up more evidence of future plans in this area.

5.2.6 Ship Construction and Installation CAD/CAM Technology Voids

Ship construction and installation activities are also poorly covered in all respects. As pre-erection outfit planning techniques are incorporated into most shipyards, and, in turn, into their CAMSs activities then applications such as electrical, sheetmetal, and woodwork installation would be an integral part of production planning and monitoring. Also more staging and accessing planning will be done as ships become more modularized. Painting has been automated in other industries though the accuracy and sheer volume (in terms of area covered) required for shipbuilding has not yet been achieved with a great deal of accuracy. However, four shipyards are planning in the near future to implement such systems which shows that development work is being done in this area. Construction, and hull erection and fairing coverage via CAD/CAM technologies should improve as real-time control systems evolve. Another weak area that has, at least, some encouraging applications currently is testing. Testing may be enhanced in the future as it is in a few current applications via by engineering/simulation programs however, testing covers quite a broad area and apparently only one other shipyard is planning a future implementation for computer assisted testing.

5.3 RECOMMENDATIONS

The survey of CAD/CAM Technology Applications in the U.S. Shipbuilding Industry has to this point identified and compiled a comprehensive view of current and immediate future (next five years) applications of computer technologies, as well as identifying strong and weak points in the U.S. shipbuilding industry's approach to computer technologies. The purpose of recommendations after such a survey is to suggest ideas that will foster an environment to reinforce the CAD/CAM technology advancements achieved to date and suggest remedies for those weak and/or void areas in the future.

Eight general recommendations are offered based on survey findings, each of which could involve a multitude of steps to accomplish its objective.

5.3.1 Strategic Planning

Shipyards and design agencies should continue to manage using those techniques sited in Table 22, Successful Management Approaches, especially those concerned with strategic management. These are upper management support, production oriented planning, planning and production staff cooperation, organizational restructuring to accommodate new methods, and management-workers/union participation in work methods restructuring. Building on these successful approaches (as well as others sited in the shipyard visits) will aid in producing an environment conducive to change, emphasizing the control over the organization's activities, and should result in improved productivity. Projects such as the Five Year National Shipbuilding Productivity Improvement Plan should be conducted on a regular basis since they provide strategic incentive.and direction to improving the shipbuilding industry as a whole.

5.3.2 Continue in Areas of CAD/CAM Technology Strength

The shipbuilding industry's primary areas of strength with respect to CAD/CAM technology implementation are computer aided design and computer assisted management systems. The vendor upgrade of computer aided design drafting systems and committee standards such as IGES have a momentum almost of their own and shipyards and design agencies should be encouraged to continue participation in the growth of these areas. CAMSs are primarily an in-house endeavor, which continues to evolve both in terms of sophistication and scope. The area most in need of futher research and development is that of initial planning, scheduling and estimating. Projects such as the Computer Aided Estimating for Shipbuilding (CAES) should continue to be funded and CAES in particular should be seriously considered for completion. In lieu of the more sophisticated data base management systems and software tools (refer to the SP-4 Software Tools Report) these resources should definitely be applied in future systems development work.

5.3.3. Coordination of the Many Advisory Groups

One area which could be of great benefit to the advancement of the U.S. Shipbuilding industry is the ability to coordinate, consolidate and communicate information and efforts of the various shipbuilding groups. This includes National Shipbuilding Research Programs (NSRP), the Shipbuilding Technology Program (STP), the Shipbuilding Production Committees (SPC), the Manufacturing Technology (MANTECH) projects, projects by the Society of Naval Architects and Marine Engineers (SNAME), the National Academy of Sciences efforts, the National Research Councils efforts and Navy research and development projects, all of which are attempting to further productivity in shipyards. T here is no logical reason why other projects cannot work together in a manner similar to the CAD/CAM survey project and the SP-4 Software Tools Project, to complement each other's efforts and further the U.S. shipbuilding industry.

5.3.4 Proper Utilization of Government Programs

Most shipyards and design agencies are familiar with the Department of Defense programs called the Indusrial Modernization Incentives Program (IMIPs). For a shipyard involved with defense work, IMIPs can provide a risk sharing environment in which to modernize. There is also the need for an effective maritime policy, which, as one shipyard suggests would only compensate for the real differences between U.S. and foreign shipyard ship production such as material cost differentials between the United States and other countries.

5.3.5 Pre-Erection Outfit Planning Techniques

The. U.S. shipbuilding industry is moving toward the methods of pre-election outfit planning. Projects that enhance and/or contribute to this trend should continue to be encouraged.

5.3.6 Automation

The shipbuilding industry should continue to be aware of and perform research and development projects in automation. The two primary areas should be the expansion of the use of numerical control equipment and material handling machinery. Robotics are being adequately investigated currently and should not be neglected, however, its potential for use within the next 10 years is quite limited for the shipbuilding industry and should not be an area of emphasis.

5.3.7 CAO/CAM Technology Transfer

Projects that promote the transfer of state-of-the-art CAD/CAM technology should be encouraged. Current studies have looked at the state of CAD/CAM applications in the shipyard (this study) and future strategies in software tools (SP-4 Software Tools Project). Another project should be conducted, which will provide insight into the state-of-the-art of the CAD/CAM technology applications in other industries and in foreign shipyards that will aid in the weak areas of U.S. shipbuilding industry. Also with the advent of sophisticated data base management systems, further investigation into the use of these types of systems should be conducted. For example, development of a generic shipyard data base design based on pre-erection outfit planning techniques as suggested by the 1982 report entitled, "A Conceptual Information Model for Outfit Planning", should be pursued.

5.3.8 Future CAD/CAH Surveys

This CAD/CAM survey serves as a valid benchmark to the current state of CAD/CAM applications in the U.S. Shipbuilding industry. Future surveys should be conducted periodically as a means of documenting the advancements and achievements of the U.S. shipbuilding industry in applying CAD/CAM technologies. Our recommendation is that an extensive survey such as this one be conducted once every five years. In fact, following similar reasoning to the timing of this survey, it provides an excellent companion to strategic planning efforts such as the Five Year National Shipbuilding Productivity Improvement Plan.

5.4 CONCLUSIONS

No one shipyard or design agency is clearly ahead of the rest. Some have a clear and strong course charted for the future but are not currently in a strong position in terms of current CAD/CAM technology implementation. Others have some technical areas where they excel but are not demonstrating a clear plan or the middle management initiative necessary to integrate their edge into an overall strategic plan. The U.S. Shipbuilding industry is right at the threshold of a major change. Most realize that major implementation of CAD/CAM technologies is inevitable and will greatly improve their operations, but, are hesitant to make a large commitment in this direction. Like swimmers waiting for the starting gun, there is a lot of anticipation but understandably no one wants to make a false start. Carrying the anology further, for the shipbuilding industry there is no one referee to pull the trigger of the starter gun as the Department of Defense's IMIPs, individual shipyards and design agencies, and government maritime policies are showing no clear leadership to begin the race to recovery.

The MarAd Five-Year Plan can be considered the touch stone (the beginnings, first attempt) in leading U.S. shipyards and government research and development efforts into an effective strategic industrial recovery plan. It is just a first plan and should be upgraded annually. The CAD/CAM survey is a snap shot in time of where the plan is now. The SP-4 Software Tools Project is a glimpse into the shipyard of the future and suggests how the plan may be achieved. Ideally the CAD/CAM surveys of the future (e.g., every five years) will monitor progress of "the plan". Coordinated MarAd/Navy research and development will provide direction to the constantly changing "plan" as it becomes increasingly accurate and achievable.

The U.S. shipbuilding industry is not behind in CAD/CAM technology implementation relative to other industries, especially the other defense industries and the construction industry. Shipbuilding's use of computer technologies is greater than the manufacturing industry's use at large, with the possible exception of commercial aerospace, and electronic companies and large Fortune 500 manufacturers. Defense aerospace and electronic industries show no real signs of implementing CAD/CAM technologies better, per dollars spent, than the shipbuilding industry, but they currently enjoy the technological advantage of not yet having to compete on the world market. Even so, these industries are fast losing their edge to other countries and should watch the recovery of the U.S. shipbuilding industry with great interest. Where the Department of Defense's research and development dollars have gone in the past such as aerospace and electronics, has enabled the U.S. to maintain the edge in those fields, but not really one of manufacturing productivity as much as being ahead scientifically. If the United States does not return to a heavily industrial engineered work breakdown structure and shift to long term incentives within our corporate structures, (or remain scientific leaders, technologically) it will inevitably lose its manufacturing edge to other countries (that do).

It is evident the U.S. shipbuilding industry is making a serious attempt to modernize through the use of CAD/CAM technology. Computer assisted management systems are one example of how systems evolution, though sometimes painful, can come about. A slow but steady shift towards pre-erection and outfit planning shows that the U.S. shipyards, despite criticism, are flexible enough to make a major change in their production philosophies. And with effective use of future research and development projects and government incentives programs, such as IMIPs, as well as the hope for some intelligent maritime policies from congress, the U.S. shipbuilding industry begins its slow approach toward recovery. It is not a clear path by any means. Even the most judicious use of projects and CAD/CAM technologies cannot guarantee that the U.S. shipbuilding industry' will ever compete effectively in the world market again; however, it is its only chance.

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APPENDIX A

CAD/CAM SURVEY QUESTIONNAIRE

GLOSSARY OF TERMS

A SURVEY OF CAD/CAM APPLICATIONS IN THE SHIPBUILDING INDUSTRY

GLOSSARY OF TERMS

SECTION 1: SHIPBUILDING FUNCTIONS TERMINOLOGY

The terms defined in this section correspond with those used In Part I of the Shipyard Questionnaire

A. Design, Drafting Production Engineering & Lofting

CODE		
1.	Hull Form Definition & Analysis	The design and structural analysis of a ship's hull form.
2.	Parts Definition:	
3.	Mechanical/Structural	The design of a ship's mechanical and structural systems such as equipment, propulsion system, and structural members.
4.	**Electrical**	The design of a ship's electrical systems and components such as wiring, fixtures and all electrical equipment.
5.	**Piping**	The design a of ship's piping systems such as steam heat and power, hot water, hydraulic, air pressure, and oil lines.
6.	Outfitting/ Accomations	The modular design of the accommodations.
7.	Parts Nesting	Arranging parts to be cut from a steel plate so as to minimize scrap.
8.	Fabrication Detail Generation	The development of sheet metal fabrication details such as bridges and leadins.
9.	Cutting Path Development	The development of the optimal path for the cutting tool to follow when cutting or milling parts.
10.	Shop Drawing Generation	The procedure of producing part and subassembly detail drawings for use in production shops.
11.	Specification Sheet Generation	The development of a list of specifications relating to materials, equipment, processes, or systems.

12. Parts Coding	The utilization of a code number to describe the characteristics of a part with its geometrical shape and/or process route for producing the part.
13. Parts Listing	The development of a list of all parts that make up a product (syn: bill of materials, indentured parts list).
14. Dimensional and Quality Control	The process of establishing acceptable limits of variation in size, weight, finish, function, etc., in order to meet specifications and enhance production efficiency.
15. Hull Fairing	A correcting process performed in "laying down the ship's lines in mold loft, to ensure the regularity or the evenness of the water lines, bow and buttock lines when transferring to full size the sheer drawing on the mold loft floor.
16. Lofting	The process of transferring the design of a vessel, in the form of specific layout and dimensions, to the shipbuilding materials.
17. Material Requirements Definition	A service function of material requirements planning that involves selecting the materials to be used; determining the specifications which the materials must meet; and listing the materials to be used, quantities required, and when each is needed.
18. Production Systems Engineering	An aspect of Design Engineering with specific emphasis on ship systems such as piping, electrical and ventilation.
19. Process Engineering	A service function of production engineering that involves selection of the processes to be used, determination of the sequence of all operations and requisition of special tools to make a product.
20. Analysis:	
21. Area/Volume	The computation of entities related to. the area and/or volume of a part during the design process.

22.	Clearances/Interferences	The analysis of ship spaces for necessary clearances to eliminate interferences between the distributive systems that run throughout a ship (piping, structural, electrical, ventilation, doorways, equipment access).
23.	Structural	The analysis for structural soundness of the support members in a ship.
24.	Other	Any other types of engineering analysis performed, such as hydrostatic, hydrodynamic, vibrational, heat transfer, finite element, and material analysis.
25.	Modeling:	
26.	Mathematical	The formulation of a mathematical equation that describes a graphical model.
27.	6eometric	Mathematically specifying a part or product by its geometric form or properties.

B. Planning and Prodction Control

28.	Work Organization	The assignment of work to separate trades, areas, and work stations.
29.	Contract Scheduling	First step in strategic planning involving milestone scheduling, establishment of progress payments, and delivery date(s).
30.	Steelwork Prodction Scheduling	A service of production scheduling which establishes the dates and production flow for the steel & plate operations.
31.	Outfit Production Scheduling	A service of production scheduling involving scheduling of pre-erection and on-board outfitting.
32.	Outfit Installation Scheduling	An aspect of outfit production scheduling which attempts to establish installation of outfitting modules.
33	Ship Construction Scheduling	A service of production scheduling involving scheduling the erection of the structural aspects of the ship.
34.	Steelwork Production Control	A service of production control which monitors and adjusts the flow of work in the steel & plate operations.

35. Outfit Production Control	A service of production control which monitors and adjusts the sequence and/or schedule of fabrication and assembly work of or in pre-erection outfitting and outfitting modules.
36. Outfit Installation Control	A service of production control which monitors and adjusts the sequence and/or schedule of the actual installation of modular and non-modular outfitting.
37. Ship Construction Control	The function of production control involving the ordering, sequencing, and execution of work including material control and provision of services.
38. Inventory Control	A function which controls excess storage and shortages of raw materials, parts and products.
39. Quality Control	A management tool for producing goods with satisfying quality characteristics by systematically establishing acceptable limits of variation in size, weight, finish, function, etc.
40. Personnel Scheduling	The assignment of individual workers to particular tasks.
41. Performance Calculations	The systems used to measure performance (accomplishment) and efficiency in terms of progress, cost to date, and work station operation.
42. Purchasing	A function which controls the flow of materials into the manufacturing plant from the vendor or supplier, either as purchased parts or raw materials.
43. Estimating	The estimation of the costs associated with building a ship based on production requirements.
44. Facilities Planning -	The activity of selection, from among alternatives, the future facility layout, or positioning functions within an operating site.
45. Naterial Flow	The actual or planned route by which raw materials and workplaces move between-work stations in connection with overall or major flow of the components into the end product or as the specific flow through any set of functions.

46. Material Handling	The function of moving workplaces between work stations.

C. Steel Work Prodction

47. Stockyard & Treatment	The storage, handling, treatment and control of plate from receipt to delivery to the cutting areas.
48. cutting	Cutting, by all means, large rectangular and non-rectangular plates, large and small internals, floors, longitudinal, webs, etc.
49. Forming	The process of converting raw materials into finished parts by deforming the metal effecting curvature and causing it to form into the desired shape.
50. Subassembly	A structural unit which though manufactured separately, was designed for incorporation with other parts in a final assembly.
51. Structural Unit Assembly	The assemblage of lower level structural subassemblies and parts into larger subassemblies.
52. Outfit Steel Work	The fabrication of masts, kingposts, hatches, foundations, bulwark, ladders, small tanks, pipe supports, etc.

D. Outfit Prodction

53. Pipework	The fabrication of pipe and fittings (e. g., bending, flanging, priming, etc.) prior to installation.
54. Engineering/ Machine Shop	A function where machining is performed (usually in batches less than 10 parts) and some sub-assembly work occurs.
55. B1acksmith Shop	The production of all shipyard supplied forged items required for installation.
56. Sheelmetal Work	The manufacture of furniture, galley equipment, ducts, wire mesh screens, etc., from 1/8″ or less stock.
57. Woodworking/Joiner shop	The manufacture of wood products including furniture, trim laminates, supports, and blocks.

58. **Electrical**

The preparation of cable, straps, and other items for installation and manufacture of components such as panels, switchboards, and consoles, and the testing of purchased components.

59. Rigging

A function which involves splicing and tying rope to form nets, ladders, and other rigging. The Rigger is also responsible for weight-handling gear and attaches hoists and pulling gear to rigging to lift, move and position heavy loads aboard ships.

60. Maintenance

The system and material support methods for maintaining yard equipment and tools used in production, including cranes.

61. Warehousing

The function of storing raw material and in-progress inventory.

E. Outfitting Activities

62. Outfitting

The process of adding non-structural and non-propulsion items to a ship (e.g., electrical and piping systems, sheet metal and joiner work, paint).

63. Module Building

A method by which a ship is divided into significant structural units (modules; e.g., bow, stern, deck house, machinery space) that are built and outfitted off location and erected essentially complete.

64. Outfit Parts Marshalling

The collection into one area of all the material, technical information, and tools needed to construct a module or discrete piece of work.

65. Pre-Erection outfitting

The installation of Pipe, cable, venti- equipment, foundations, and components within a structural unit, or structural module prior to erection.

66. Block Assembly

The installation of previously assembled package units into a larger block assembly.

67. Unit and Block Storage

Inventory control of work-in-progress unit and block assemblies.

F. Ship Construction & Installation

68. Ship Construction	The general construction process including installation of subassemblies, equipment, modules, etc. at the construction site.
69. Hull Erection and Fairing	The alignment, fairing, and erection of the hull at the construction site.
70. Welding	A metal joining process in which coalescence is obtained by heat and/or pressure.
71. Staging and Access	The support structure for the hull at the construction site and the catwalks and ladders providing access.
72. Pipework	The installation of a ship's pipe, valves, and other pipework.
73. Engine Roam Machinery	The installation of heavy equipment such as propelling equipment, auxiliary motors, heaters, and pumps in units, blocks, or the ship after erection.
74. Hull Engineering	The installation of deck machinery (e.g., steering gear, winches, windlasses) in units, blocks, or the ship after erection.
75. Sheetmetal Work Installation	The installation of sheetmetal products (e. g., ducts, galley equipment, vents) in units, blocks, or the ship after erection.
76. Woodwork Installation	The installation of wood products (e.g., panels, furniture, blocks, shores) in units, blocks, or the ship after erection.
77. Electrical Installation	The function involving installation and repair to wiring, fixtures and equipment for all electrical services aboard ship and in shipyard facilities.
78. Painting	The function of priming and painting a ship structure and outfit including plates and stiffeners from stockyard.
79. Testing	The final test of mechanical and electrical systems, and sea trials involving builder, preliminary acceptance and acceptance trials.

GLOSSARY OF TERMS

SECTION II: COMPUTER TECHNOLOGY TERMINOLOGY

The terms defined in this section correspond with those used in Part II of the Shipyard Questionnaire.

I. Computer Aided Design

CODE		
1.	Automated Drafting	Generation of engineering drawings from data base descriptions of a real artifact.
2.	Bill of Materials Generation	Generation of a list of all the sub-assemblies, parts, & materials that constitute an assembled product showing the quantity of each required to make one assembly.
3.	Computer Aided Hull Definition	Computer aided method for determining hull offsets and defining the shape of a hull.
4.	Computer Aided Hull Fairing	Computer aided method for the mathematical definition of a smooth or fair hull surface.
5.	Group Technology	The means of coding designs parts on the basis of their similarities. (See also #29).
6.	Interactive Graphics	The use of interactive computer displays with graphical input/output devices to depict a product, subassembly, or part.
7.	Parts Definition	The design and definition of parts and subassemblies.
8.	Solids Modeling	Usage of interactive graphics to provide a complete description of solid objects constructed from conbinations of solid primitives.

II. Computer Aided Engineering Analysis

9. Heat Transfer Analysis	Determining the effects of heat generation on the ship's structure and the propulsion capability.
10. Hydrodynamic Analysis	Computer aided method for determining forces on a ship in motion (i.e. resistance, ship motions, slamming, etc.).
11. Hydrostatic Analysis	Computer aided method for determining forces on a ship stationary in the water (i.e., stability, sinkage & trim, displacements, etc.).
12. Material Analysis	Determining the suitability of materials for use on a hull structure (i.e. fouling resistance, strength of material, corrosive properties).
13. Structural Analysis	Determining the structural soundness of a hull form.
14. Vibrational Analysis	Determining the effects on the ship structure due to vibrational forces (i.e. ship's engine).

III. N/C Process Control

15. N/C Cutting	Numerically controlled cutting of metal plates to desired shape.
16. N/C Frame Bending	Numerically controlled bending of frame. pieces.
17. N/C Machining	Numerically controlled machining of products (i.e. lathe, drill).
18. N/C Pipe Bending	Numerically controlled bending of pipes to desired angle.
19. N/C Programing	Programming of numerically controlled (N/C) machine tools, flame cutter, and other similar equipment.
20. H/C Shell Plate Development	Development of curved plates on hull surfaces so that they can be cut out from a flat plate.
21. N/C Tape Verification	Using graphics peripherals to determine the correctness of an N/C tape's programmed actions.

22. N/C Welding	Numerically controlled metal welding.
23. N/C Surface Preparation and Coating	Numerically controlled preparation of the hull surface (i.e. sanding, washing, painting).

IV. Manufacturing Technologies

24. Computer Aided Die Design	Computerized method of designing dies while taking into account such factors as shrinkage, deformation, stress, etc., depending on die type.
25. Computer Aided Lofting	Use of a computer to define lines representing a hull form from which full scale lofting lines can be obtained.
26. Computer Aided Parts Nesting	Use of a computer to arrange the various parts for cutting from plate or sheetmetal so that the most effective use of material is achieved.
27. Computer Aided Process Planning	Creation of production process plans for items in a given family with either partial or total computer assistance.
28. Computer Aided Time Standard Generation	System for determining the time duration for completing a task given various constraints such as equipment and personnel availability, plant layout, etc.
29. Group Technology	1) The grouping of parts into production families based on production process similarities so that parts in a particular "family" can be processed together. 2) The grouping of diverse machines together to produce a particular family of parts. (See also #5)

V. Computer Assisted Management Systems

30. Control/Status Reporting Systems	Computerized real time monitoring of production progress including work-in-process procurement, material handling, & work package status.

31. Facilities Planning:	Use of a computer system for determining the physical layout of facilities or equipment to produce a certain product.
32. Plant Layout	Locating functions within a facility.
33. Economic Evaluation	Determining economic feasibility of facilities locations.
34. Materials Requirements Planning	Computerized production and inventory control sytem for reducing inventory improving customer delivery schedules and properly utilizing plant capacity.
35. PERT/CPM	Program Evaluation and Review Technique/ Critical Path Method. A computerized project planning and monitoring system used to detrmine optimum schedules, project duration, cost constraints, current status information, "critical path" determination, etc.
36. Planning Systems	Use of computerized techniques to aid in the strategic, tactical, and implementation planning functions.
37. Production Crew Assignment/Loading	Use of the computer for finite capacity scheduling of employees by skill types and availability to discrete elements of work.
38. Quality Assurance systems	Computer performed activities to ensure that the product conforms to desired specifications.
39. Scheduling System	Use of the computer to relate specific events to specific times or to a specific span of time, so as to maximize facility and personnel usage and minimize production time.

VI. Automation

40. Automated Materials Handling	Computer controlled method of moving work pieces between work stations.
41. Automated Storage and Retrieval	Computer-operated part pickers and stockers.

42. Flexible Automated Mfg. system	Computer controlled manufacturing systems that can be easily reconfigured to meet the requirements of a specified process or workorder.
43. Instrumentation and Testing	Computer controlled instruments used for the testing of a product to ensure that required specifications are met.
44. Robotics	Usage of an automatic, programmable device for performing specified tasks and functions.

A P P E N D I X   B

THE CAD/CAM SURVEY QUESTIONNAIRE

PART I: COMPUTER TECHNOLOGIES AND SHIPBUILDING FUNCTIONS

For each of the shipbuilding functions listed below, please indicate which are aided at your yard by one of the six computer technology areas described using the following rating system in indicating your applications:

+ = Successful Application
✓ = Satisfactory Application
- = Unsatisfactory Application
N = New Application
F = Application Planned for Future Implementation

For example, if your organization is very satisfied with its application of interactive graphics to "hull form definition and analysis", a "+" would appear under Column 1 on Line 1.

CODE	SHIPBUILDING FUNCTIONS	COMPUTER TECHNOLOGY AREAS I. Computer Aided Design	II. Computer Aided Engineering Analysis	III. N/C Process Control	IV. Manufacturing Technologies	V. Computer Assisted Management Systems	VI. Automation
	A1. Design, Drafting, and Engineering						
1.	Hull Form Def. & Analysis						
2.	Parts Definition:						
3.	Mechanical/Structural						
4.	Electrical						
5.	Piping						
6.	Outfitting/accommodations						
7.	Shop Drawing Generation						
8.	Specification Sheet Generation						
9.	Parts Coding						
10.	Parts Listing						
11.	Matl. Requirements Definition						
12.	Production System Engineering						
13.	Analysis:						
14.	Area/Volume						
15.	Clearances/Interferences						
16.	Structural						
17.	Other Analysis						
18.	Modeling:						
19.	Mathematical						
20.	Geometric						
	A2. Production Engineering and Lofting						
21.	Parts Nesting						
22.	Fabrication Detail Generation						
23.	Cutting Path Development						
24.	Dimensional & Quality Control						
25.	Hull Fairing:						
26.	Lofting						
27.	Process Engineering						
	B. Planning and Production Control						
28.	Work Organization						
29.	Contract Scheduling						
30.	Steelwork Production Scheduling						
31.	Outfit Production Scheduling						
32.	Outfit Installation Scheduling						
33.	Ship Construction Scheduling						
34.	Steelwork Production Control						
35.	Outfit Production Control						
36.	Outfit Installation Control						
37.	Ship Construction Control						
38.	Inventory Control						
39.	Quality Control						
40.	Personnel Scheduling						
41.	Performance Calculations						
42.	Purchasing						
43.	Estimating						
44.	Facilities Planning						
45.	Material Flow						
46.	Material Handling						
	C. Steelwork Production						
47.	Stockyard & Treatment						
48.	Cutting						
49.	Forming						
50.	Subassembly						
51.	Structural Unit Assembly						
52.	Outfit Steelwork						
	D. Manufacturing and Production Activities						
53.	Pipework						
54.	Engineering/Machine Shop						
55.	Blacksmith Shop						
56.	Sheetmetal Work						
57.	Woodworking/Joiner Shop						
58.	Electrical						
59.	Rigging						
60.	Maintenance						
61.	Warehousing						
	E. Pre-Erection Outfitting Activities						
62.	Outfitting						
63.	Module Building						
64.	Outfit Parts Marshalling						
65.	Pre-Erection Outfitting						
66.	Block Assembly						
67.	Unit and Block Storage						
	F. Ship Constr. & Installation						
68.	Ship Construction						
69.	Hull Erection and Fairing						
70.	Welding						
71.	Staging and Access						
72.	Pipework						
73.	Engine Room Machinery						
74.	Hull Engineering						
75.	Sheetmetal Work Installation						
76.	Woodwork Installation						
77.	Electrical Installation						
78.	Painting						
79.	Testing						

COMPUTER TECHNOLOGY APPLICATION DETAILS

computer technologies are listed below. For each of those in use in your yard, please complete the Detail questions appearing in columns A thru F.

CODE	COMPUTER TECHNOLOGIES	APPLICATION DETAILS A. Shipyard Function(s) Applied to (Refer to Code numbers in Part One)	B. Indicate Software Vendor (Or In-House Developed)	C. Software Modified In-House? (Yes/No)	D. Integrated with Other Systems? (Indicate which referring to Code numbers on this page)	E. Years in Use	F. Applic. Success (Scale of 1-10 with 10 best
	I. Computer Aided Design						
1.	Automated Drafting						
2.	Bill of Material Generation						
3.	Computer Aided Hull Definition						
4.	Computer Aided Hull Fairing						
5.	Group Technology						
6.	Interactive Graphics						
7.	Parts Definition						
8.	Solids Modeling						
	II. Computer Aided Engineering Analysis						
9.	Heat Transfer Analysis						
10.	Hydrodynamic Analysis						
11.	Hydrostatic Analysis						
12.	Material Analysis						
13.	Structural Analysis						
14.	Vibrational Analysis						
	III. N/C Process Control						
15.	N/C Cutting						
16.	N/C Frame Bending						
17.	N/C Machining						
18.	N/C Pipe Bending						
19.	N/C Programming						
20.	N/C Shell Plate Development						
21.	N/C Tape Verification						
22.	N/C Welding						
23.	N/C Surface Prep. and Coating						
	IV. Manufacturing Technologies						
24.	Computer Aided Die Design						
25.	Computer Aided Lofting						
26.	Computer Aided Parts Nesting						
27.	Computer Aided Process Planning						
28.	Comp. Aided Time Standard Gen.						
29.	Group Technology						
	V. Computer Assisted Management Systems						
30.	Control/Status Reporting Systems						
31.	Facilities Planning:						
32.	Plant Layout						
33.	Economic Evaluation						
34.	Materials Requirements Planning						
35.	PERT/CPM						
36.	Planning Systems						
37.	Produc'n. Crew Assignment/Loading						
38.	Quality Assurance Systems						
39.	Scheduling Systems						
	VI. Automation						
40.	Automated Materials Handling						
41.	Automated Storage and Retrieval						
42.	Flexible Automated Mfg. Systems						
43.	Instrumentation and Testing						
44.	Robotics						

VII. OTHER (Please specify)

PART III: COMPUTER TECHNOLOGY BENEFITS AND PROBLEMS

A. POTENTIAL BENEFITS

Listed below are a number of potential benefit areas commonly associated with computerization and automation. Please indicate those benefits which have affected your operations as a result of the implementation of new technologies from the six general Computer Technology Areas listed. Use the following rating system.

+ = Substantial Benefit Observed
= Some Benefit Observed
0 = No Benefit Observed

For example if your organization has realized "substantial" benefits in the area of material handling resulting from an "automated materials handling" system and "computerized materials requirements planning" system, a "+" would appear in columns V and VI on Line 12.

POTENTIAL BENEFIT AREAS	COMPUTER TECHNOLOGY AREAS					
	I.	II.	III.	IV.	V.	VI.
	Computer Aided Design	Computer Aided Engineering Analysis	N/C Process Control	Manufacturing Technologies	Computer Assisted Management Systems	Automation
1. Leadtime						
2. Control						
3. Scheduling						
4 Planning						
5. Standardization						
6. Producibility						
7. Product Quality						
8. Integration						
9. Facilities Planning/Utilization						
10. Procurement						
11. Labor						
12. Material Handling						
13. Production Productivity						
14. Flexibility						
15. Safety						

B. POTENTIAL PROBLEMS

Listed below are a number of potential problem areas commonly associated with computerization and automation. Please indicate those which have affected your operations as a result of the implementation of new technologies from the six general Computer Technology Areas described. Use the following rating system in describing the problems observed:

+ = Substantial Problem Observed
= Some Problem Observed
0 = No Problem Observed

POTENTIAL PROBLEM AREAS	COMPUTER TECHNOLOGY AREAS					
	I.	II.	III.	IV.	V.	VI.
	Computer Aided Design	Computer Aided Engineering Analysis	N/C Process Control	Manufacturing Technologies	Computer Assisted Management Systems	Automation
1. Software Maintenance/Support						
2. Hardware Maintenance/Support						
3. User Acceptance						
4. Support Personnel						
5. User Skills						
6. Implementation						
7. Training						
8. System's User Friendliness						
9. Information Retrieval						
10. Information Integrity						
11. Capitalization						
12. Integration (With Other Systems)						

C. OTHER BENEFITS/PROBLEMS (EXPLAIN):

APPENDIX C

SHIPYARD VISIT SUMMARIES

DESIGN AGENT B

1. Computer-Aided Design

Design Agent B utilizes the CADAM and SPADES software packages in their automated drafting procedure. They have future plans to acquire a 3-D modeling system which would be used in conceptual design applications. Currently there is no direct tie between CADAM and SPADES, though an interface is being looked into and there are future plans to implement such a system. Design Agent B also has available HULDEF and SPADES for work in hull definition and hull fairing. Currently they use their CAD system on mechanical and structural parts, piping, and outfitting/accommodation design work. Understandably they are not heavily involved in the electrical design work and therefore are not applying their CAD system to this application.

Design Agent B applies their computer aided design and computer aided engineering analysis packages not only to traditional production systems engineering but they also have the capability to apply it to outfit and pre-errection outfit planning activity. In fact they are currently involved in one contract in which they are converting to outfit planning modules or units in the detailed design phase.

If CAD were compared with the straight first time drafting function they feel they would easily get a two to one productivity gain. However, the CAD system allows them much greater productivity gains further downstream with greater ease of changes to existing drawings and the ability to perform the engineering analysis and various other activities which concern adjustments and modifications to those drawings. In the future they see an advantage to the 3-D modeling systems for conceptualizing the design. However they feel that they would stick with 2-D drafting type systems for the actual drawing phase of the design function. To do this it will be important to have an interface from the 3-D system to go directly into the 2-D system otherwise productivity would be lost by having to duplicate and re-enter data from one system to the next. This may also cause an integrity problem from one set of data to the next. Currently their CADAM and SPADES as well as the HULDEF system are not interacting with each other and this is also an area of concern they will be looking into in the future. Currently re-entry of data is done from the CADAM system to the SPADES system and vice-versa in the manual mode.

Currently their CADAM system is located on a Perkins-Elmer computer and they have 15 CADAM terminals with 19-inch screens. They claim that 50% of the drafting is done on the CADAM system and 60% of their engineers are trained to use this system. Because of the shortage of terminals they operate CADAM on a 3 shift basis.

Their organizational layout for design work consist of 4 different departments these are the hull, machinery, electrical, structural, and auxiliary (for special work) departments. They also have a special QA group which is small and a complete library of specifications and manuals, as well as the ability to write computer support services. Some of the producibility factors this design agency tries to plan for include reducing the number of total pieces, and whether or not the ship sections involve repetitive construction methods. A common approach for Design Agent B on **new** design is, on the first pass, to design based on the strength of the ship using acceptable minimums. Then on the second pass evaluating the commonly available. materials which would probably. be used in the construction and perform weight analysis to see that the ships still falls within acceptable limits.

2. Computer-Aided Engineering Analysis

Design Agent B has the ability to perform hydrodynamic analysis with the use of scores or NSDRC, hydrostatic with SHCP or SPADES, structural analysis the use of NSTRAN and STRUPAC, and vibrational analysis with NASTRAN and INTODAM.

Design Agent B applies these packages in hull form definition and analysis, mechanical, electrical and piping analysis for hull fairing production systems engineering, area and volume analysis, structural and electrical analysis as well as systems modeling. A new application for them is in the area of clearances and interferences.

3. N/C Process Control

Understandably there are no numerical control process application for the design agent however there are future plans to be able to generate N/C process control tapes for mechanical/structural parts as well as lofting. The concept here being the ability to obtain the tapes for steel plate cutting and the other lofting type requirements.

4. Manufacturing Technologies

The Design Agent B intends to have a future application in the mechanical/structural area, however it is not clear at this time what those particularly reference, unless it is further capability in defining numerical control tape for automatic machine language generation.

5. Computer-Assisted Management Systems

Currently Design Agent B has the capability to generate the specification sheet based on its computer assisted management systems. There is further intent on their part to be able to generate pas coding and parts listings as well as lofting information requirements.

As far as internal management and control of the drafting activity they have a system for general project management. This simply means that once they get their contract in and approved their accounting system is set up to accrue labor hours against it. There is no particularly formal mechanism other than normal time sheet collection and accounting processing required by this kind of system. This kind of contract scheduling system depends heavily on management supervision to implement an effective plan because the system itself does not really set up any detailed parameters such as hours allocated for each drawing, etc. This kind of monitoring system is quite adequate however when estimates are good and the contractor follows charges accrued on a relatively regular basis.

6. Automation

There is no-reason to expect computer technologies relating to automation to exist at a Design Agent and in fact, in this case, they do not.

7. Summary

A Design Agent can serve several functions. Most noticeably for the smaller shipyards who cannot reasonably assume the risk of a heavily staffed design deparment it offers them the ability to team or contract with a design agent for those functions. In general, they are a ready source proven hull forms and modifications and have extensive experience in optimizing ship design both structurally in terms of intenal arrangements. For the larger shipyards they can fill two roles primarily, first is that of an overflow function to provide extra contract services for design and drafting and secondly and more importantly they could in fact provide not only initial design concepts to the shipyard but also the ability to interface between shipyards on a contract. With the heavy uses of computer aided design and computer aided engineering analysis and the flexibility to work either structurally or in an outfit planning mode it would enable them to be the middle man between lead yard and follow yards, if such were the case, and also provide them with the ability to pass on their conceptual and new design information to the actual construction contractor on a project. Ideally their data base would be able to converse or interface with the data bases available at a shipyard. However, right now its difficult enough of a problem to be able to interface from one system to another within a company so this problem needs to be addressed immediately and in the long term the yard to design agent interface could be considered.

Design Agent B finds that the primary benefits derived from computer technologies included increased standardization, product quality, scheduling and producibility overall then they feel that computer technologies have helped them be more responsive to design deadlines and improved quality of their design work. The larges problem they are having is with integration between systems followed closely by system user friendliness, software maintenance/support, and human factors of user skills, implementation, and training. Since much of their work involves going back and forth from conceptual design, detailed design and engineering analysis, it is understandable that they are plagued by the inability of software from one package to communicate with the-software of other related packages.

Shipyard D

Shipyard D is primarily a repair yard of late, though they have worked on some new construction and in the past were primarily oriented in that direction. They would fall into medium user category of computer technologies and their utilization resides primarily in lofting. Most of their existing computer technologies are somewhat dated and there is an acknowledgment of a need to re-evaluate computer applications. The catch 22 that many shipyards are in is that they need computer technologies to assist them in competing thus bring in business but until they bring in business it is very difficult to find the funds to computerize. The other side of that coin is that while there is some slack time in your engineering staff now, in a recessive business period, would be an excellent time to be able to implement computer technologies in the proper way.

1. Computer-Aided Design

Their computer aided design capabilities mostly exist under the auspices of lofting. In-the fact that they have the ability to plot on a printer mechanical and structural part definitions and go through the nesting and cutting path development stages. None of these functions are what are typically consider computer aided graphics, however, in a sense it certainly is computer assisted design. They have been able to achieve maximum efficiencies with only a very limited array of computer technologies available to them. In other words they are utilizing their capability to do lofting very thoroughly even upwards into the design sense, even though this is somewhat of an unorthodox and difficult manner of utilizing computer technologies it has allowed them to achieve their desired results.

2. Coaputer-Assisted Engineering Analysis

Shipyard D does have SHCP available however there is very little application of other types of computer aided engineering analysis. This is a case where the design agent is relied on heavily for these kinds of information. Of course when new construction was going at a higher pace and it was much easier to justify the added staff which perform these functions.

3. N/C Process Controls

NC Process Control is definitely Shipyard D's strength. Even though they are utilizing a somewhat older Kongsberg system they have developed several inhouse aides in which to make this more useful. Granted that most of these have been developed and established for some ten years now. They are utilizing NC process control for cutting primarily and then have a quasi-digitizing arrangement for hull boring. The type of N/C equipment in this shipyard is a G&C Oxy acetylene cutting machine with a Kongsberg control, GNC Plasma Arc cutting machine also with a Kongsberg control as well as the digitizing hull boring machine. This type of equipment for steel plate work is not uncommon in many of the shipyards visited. Neither is the age of the equiment or the type of controller.

4. Manufacturing Technologies

Once again the manufacturing technology classifications consist of the computer aided lofting and computer aided parts nesting programs which they have developed inhouse.

5. Computer-Assisted Management Systems

Shipyard D has the somewhat casual approach to utilizing a computer assisted management system. They have developed an inhouse system for control/status reporting, and planning. They utilize the IBM CYRIS and PERT programs for material requirement planning as well as critical path determination. However they do not necessarily always utilize these systems and in fact are selective on which jobs they want to monitor through their reporting systern.

In terms of their planning system it does not necessarily contain standards. They find that it is necessary to use judgement to pull together the standards for a job based on the circumstances surrounding that job as opposed to coming up with a standard data base times. Often times, the jobs they get in require a very fast pace over a short period of time therefore, it is not long enough for their system to be of full use to report on efficiency. They typically process the supervisors hourly sheets in the evening and generate a performance once per week. They do keep inventory on a daily basis and monitor receiving roughly on a daily basis.

Their planning system basically consist of a forecast based on a judgement call looking forward 10 days to estimate their workload. Their system is adequate to their current workload and fulfills many of the basic contract monitoring information needs that they have. However the system is quite inflexible and requires a great deal Of manual manipulation to utilize.

6. Automation

No automation at this time.

7. Summary

Shipyard D has worked on a variety of projects. One of their primary specialties lately is adding mid-sections or jumboizing ships. They have done this to oceanographic, slug, barges, hydrofoils, Naval PAKB-1's, and two coastal freighter vessels. They are down from 1400 people to 500 currently. The bottom line currently is that business is down drastically, however, their parent organization has promised several million dollars to be used for their modernization. The actual extent that this will go into plant facilities versus computer technologies is not known. However it is very encouraging that they have this kind of comittment to get back into a competitive position.

This shipyard certainly has the physical capacity and skilled employees to operate an effective shipyard. To the extent they can become competitive and prove their productivity depends a great deal on how their modernization money is spent. Granted that enhanced facilities are desirable, however it would be a mistake to overlook the potential of applying computer technologies. This shipyard certainly has the capability to move into outfit planning since a great deal of their experience recently has been in adding modular sections into ships. Though there is no formal plan to go that route.

SHIPYARD E

Shipyard E has requested that their visit summary be withheld from publication. Therefore, it is not available for review. Their questionnaire is included in the overall statistics, however, and their participation has been useful for the survey overall.

Shipyard K

General Observations

This shipyard has a great deal of crane capacity and physical area available. Instead of a dry dock configuration or a graving dock they use a system of dry dock and land skids to actually construct the ship entirely out of the water on solid ground. In the case of new ship construction they can build the ship on land, roll it down onto the dry dock and then launch it from there. For ship repair, just the reverse process occurs to get it onto the land, and it is launched in a similar manner as new ship construction. There is almost no computer-aided manufacturing on the production side of this shipyard except some N/C cutting. This shipyard has the potential to be the most pre-erection and erection outfitting-oriented shipbuilder in the United States. The management structure is very outfit-oriented with a very systematic chain of command geared along the work breakdown structure line. All of the power for design and scheduling originates in the planning department which takes a ship design (in a planning sense) all the way from conceptual design to modular production definition (work packages and work orders). From this point on everything is tracked by a work order, including the actual drafting time all the way through to specific direct production labor. Labor has been granted added flexibility by the unions so that this shipyard may pursue more outfitting assembly endeavors (reducing cost and indirectly saving jobs), an opportunity not available at every U.S. shipyard. Though if the current recession continues to exist it might be possible to see unions being more flexible with shipyards in the near future, therefore allowing them to gear up for outfit planning using less labor.

Recently Shipyard K's computer technology emphasis has been almost entirely aimed at their management systems which are very new. They designed it in-house, taking advantage of their old systems but otherwise totally redesigning it around a new production-oriented management style. With assistance from an experienced outside consulting firm, the shipyard was able to develop an incredibly powerful system in a short period of time. Now, as the system becomes more a part of their normal procedure, engineering and design applications will be revisited by the shipyard. With this .summary it is time to look- more specifically at each computer technology application in the shipyard.

1. Design, Drafting and Engineering

There is currently no computer-aided design drafting system at Shipyard K. There are future plans to implement SPADES and a 3-D solids modeling-type CAD system. Even though there is currently no CAD drafting system, it is useful to note that their management system does have a catalog of all standard parts and even special parts and materials that they will be procuring or fabricating. It will be observed later, under the category of computer-aided management systems, how this coding scheme of materials in parts is extremely useful to them, both in terms of designing the ship and in terms of procurement and procurement-related information.

There seem to be a few prevailing strategies on 3-D Solids Modeling systems and computer-aided drafting systems. One of these strategies is to have a 3-D solids modeling system for use in conceptual design and then referring back on a 2- or 2-1/2 D CAD system for design drafting efficiencies. A second alternative is to use a 3-D solids modeling system all the way through from conceptual design to the actual drafting. Finally, the other alternative is to use a 2- or 2-1/2 D computer-aided design system from the very beginning and carry it all the way through the drafting phases. Shipyard K envisions using a 3-D drafting system all the way through. In their particular case, they have a prime 550 computer which they will probably use for the computer-aided design system, and they might be incorporating (in the future) a program called MEDUSA which is currently marketed in the United States by Prime Computer Systems. They are also contemplating installing SPADES. Planning for a CAD system is simply in the investigation stages at this point for Shipyard K. No definite commitments have been made, though they are probably closer to implementing SPADES than MEDUSA.

2. Computer Aided Engineering Analysis

Shipyard K has quite a few useful tools in the computer-aided engineering area. Although most were developed under the previous owner, many are still relatively newly developed. The survey questionnaire indicates that they have had only one year in use with most of these systems. Many of these systems are expansions on MARAD, NAVSEA, and/or Navy programs; however, quite a bit of in-house effort was spent on expanding their capabilities. Heat transfer. analysis is mostly an in-house program. For hydrodynamic analysis, Shipyard K has taken the NAVSEA program SEALOAD and used it as a basis for expansion in-house. For hydrostatic analysis, they have used SHCP as a base and then modified it in-house; however, it was not changed as extensively as SEALOAD. For structural analysis, again, its SHCP as a base with a great deal of in-house modification; and for vibrational analysis, they programmed their own, totally in-house, which primarily is used to check if there is any critical resonance encountered in any of the horizontal or veritical shafts which make up the hull and frame of the ship.

Shipyard K's current capabilities for its computer-aided engineering analysis programs are Hull Form Definition and Analysis, Cutting Path Development and Lofting. A new feature is a Parts Nesting routine, most likely for steel fabrication. Future applications, of course, will come with the assistance of SPADES (if it is indeed purchased) which would be looking at mechanical and structural definitions, shop drawing generation, hull fairing, production systems engineering, and checking for clearances and interferences. On the more pure analysis side of the coin, programs discussed in the previous paragraph allow for clearance/interference analysis, structural analysis and the other analyses which include heat transfer, hydrodynamics, etc.

3. N/C Process Controll

Most of Shipyard K's N/C process control capabilities involve structural steel cutting. It does not appear that they have a great deal of other N/C equipment, such as general purpose machining centers or N/C milling etc. The other N/C type equipment basically has to do with lofting. For example Kongsberg N/C cutting equipment, as well as N/C tape verification. At one point in time, there was the thought of converting ALGOLS STEERBEAR program to Fortran but this was not completed.

4. Manufacturing Technologies

Shipyard K does not report any particular application of computer-assisted manufacturing technologies; however, there is one future plan in the design lofting-area, if they pursue the SPADES program.

5. Computer-Assisted Management System

Shipyard K has a very new and very comprehensive computer-assisted management system. It is set up totally on the outfit planning concept, both structural and nonstructural. They developed this system basically from their previous production work order and control system; however, they primarily revamped and redesigned the whole system. This was done requiring roughly two man-years effort over the course of 9 to 12 months, and they utilized the services of a major software contract house in the redesign process (for programming only). The important aspect of the redesign is really the fact that the shipyard itself defines what the flow of information will be and what the requirements were for its development. The software consulting firm then assisted them in achieving their own ojective. The alternative was either to have tried to buy a CAMS package and tried to adjust their system to fit it, or to hire a software firm to come in and totally do a custom system for them. It's much more difficult to expect the latter two alternatives to produce useful constructive results because they are not a part of that company's own style and, therefore, do not tend to be incorporated as wholehearted as if its the company's own design.

The computer-assisted management information system does not begin at the planning stages; it begins right afterwards. This means that the planning is not done in the computer-assist mode; however, the system they have gives sufficient query ability to be able to look back at historical data. Needless to say, however, the estimating and planning functions are done as they have always been done manually by the company's planners' intuition and best-guess estimates.

Planning is done in a heavily pre-erection outfit planning orientation mode. They basically look at three phases of production. Phase 1 consists of all the units that when completed could be preblast and preprinted before these units are put on block and on the ship. Phase two consists of all block and erection planning. And the final phase consist of the on-board outfitting. Shipyard K plans structural and nonstructural units at the same time, as opposed to many other shipyards which would consider them separate entities. This enables them to have greater flexibility in their production schedules and greater integration of structural and nonstructural units. Once the schedule is set up this way into the computer management system there is no room for deviation. Actuals are accrued against the plan and when they fall behind, the plan is not changed in the computer even though work around plans may be necessary. This puts the additional pressure on production and planning to devise a plan to get back to schedule. In a heavily sequential pre-erection plan, those critical units need to keep up to the original plan, otherwise production downstream become severely impaired. However, it is a bit easier to play catch-up on a unit and block-basis then it is in the traditional system-basis. By not changing the planned mode of operation, this forces them in small increments to keep up to the schedule that they have set. The actuals will inform them for their next round of planning where problems were encountered and where they could possibly be avoided later.

In a sense, the management system is very streamlined to go in one direction, from planning through production. Without the ability of feedback, this could be a real problem. However, since they are very module-and pre-erection outfit planning-oriented, there is quite a bit of involvement on the production and planning level. Planning is forced to respond to production needs, and production forced to be accountable to the planning mode. So the computer system really provides more of the one way communication, but the net result is a more indepth feedback outside the computer system itself. They are currently determining how to expand the feedback capabilities at this time.

The computer-assisted management system is one system, as opposed to many, and is primarily a control and tracking system since planning itself does the scheduling. First, scheduling takes the estimated funds and allocates those into detailed budgets by work packages. These work packages are then broken down into specific work orders. A work order can consist of several department's time, beginning with the engineering time needed for detailed drawings and carried all the way through the trades and special considerations such as staging. The system is hierarchical. Once the schedule is locked, the users can only get information that is appropriate for their jobs and, even then, few can actually change information or actuals in the system. Information can be retrieved from the system in the form of general information on a work package, specific information on a work order, information by department or trade classification, by physical work center (referred to as GATES) which can be a given shop or pier location, and by work group, such as through the foreman. Being able to retrieve information in this manner allows upper- and middle-line management the ability to pinpoint the source of delays or inefficiencies and take corrective actions.

The procurement system is fairly elaborate. When the plans are entered into the scheduling and control system, they are also entered by specific work order and general work package, by stock codes which are also procurement codes. This allows procurement to group some codes together for procurement purposes. They can then receive the advantages of bulk ordering, but then have those orders delivered in a time-phased manner based on the schedule. Also, since much of the initial planning goes down to the unit and block level, much of the procurement can be decided in advance of detailed design. Therefore, procurement has a chance to preview the overall ship purchasing requirements and isolate long lead time items, as well as the ability to bulk order. The management systems and procurement systems are not directly tied into a computer-aided design data base; however, when Shipyard K decides to obtain a computer-aided design tool, it could be easily arranged to have it interface with these systems.

The management system, of course, tracks actual hours incurred, and there are plans for it to be able to track material allocation as well. Initial work is being done on a steel tracking system, and in the conceptual design stages are more elaborate tracking of all materials. Once this is accomplished, it will complete the necessary closed loop system which allocates materials and labor to specific work orders and more general work packages, providing full statusing capability of outfitting work to be done.

This computer-assisted management system will probably work well for several reasons. First off, it is the invaluable upper-management commitment, not only to its use but, also, taking a hand in the planning of the system itself. The planners are in touch with the real world of production and construction because many of them are ex-foreman off the floor. Certain unfortunate circumstances are also contributing to the success of this system, because this Shipyard has been able to totally rethink the process through a closure and reopening process. This has allowed trade flexibility in union negotiation as well. Also, the systems department, and by system is meant computer system, is separate from the actual programming staff. The systems analysts are actually knowledgeable and, often times, represent people from the various departments from the shipyard itself. This is a matter of preference because arguments for the other arrangements having programmers and system analyst being the same group could also be argued convincingly. And, also, the very important aspect that the management system is the shipyard's own design.

Since they were able to redesign the system essentially from scratch, they were able to take advantage of the hardware characteristics of the computer they were planning on running it against. With the assistance of the software consultant, they structured the computer-assisted management system such that it could be addressed by the IBM query system. This meant that when they needed special reports for special gatherings of information, they could obtain it through the query routines that were available with the equipment, as opposed to writing elaborate systems programs that they would use just once or twice. This is seen as an advantage currently and maybe always will be; however, it does mean that they will probably lock in to one main computer vendor for the duration of the system.

6. Automation

There is really nothing to discuss in-the sense of automation because there is none at Shipyard K. This is not untypical because automation, such as material handling or automated storage and retrieval systems, robotics, etc., are not typically applied in the shipyard.

7. Summary and Conclusions

Overall, Shipyard K has a very impressive computer-assisted management system. They seem to be quite far along with the ability to utilize outfit-planning techniques which are, in fact, integrated and compatible with their management system. Currently, while very strong in the computer-assisted management system area, they are fairly weak in the area of engineering analysis and computer-aided design. They do have plans to go further into these areas but do not show the same systems approach and structure that they must have had in place to put together the computer-assisted management system. Since they are just completing the management system this is understandable, and could be predicted that the same type of approach will be done when they have more time to divert toward the engineering and design end. The primary benefits they see computer technology as contributing to are lead time, control, and product quality, respectively, and subsequently almost all benefits associated with the management systems except safety. While they have not experienced too much on the problem area side, they have had some typical problems. On the engineering analysis side, software maintenance and support and system user-friendliness were the problems. And on the computer-assisted management system, again, software maintenance and support as a continuing obligation, user-acceptance, user-skills, and implementation. Overall, they feel very confident in their methods and their new system and hope to enhance areas in the future.

SHIPYARD M

Shipyard M has made a commitment to the implementation of outfit planning methods and are currently in the beginning phases of evaluating the impact this will have on their computer technologies. Of the shipyards surveyed they had one of the widest variety of different systems in use. In the case of engineering design applications, these systems were well integrated. Their primary computer engineering tool (SPADES) and their primary graphics tool (CADAM) are well interfaced and heavily utilized at the shipyard. However most of their computer-assisted management systems are stand-alone programs or are not well integrated or interfaced together.

In the mid 70's their production mix changed from a primarily commercial base to a government production base. Because of their previous experience Shipyard M was quite familiar with dealing directly with the end buyer and was set-up for a lot of inhouse preliminary design work. However, the shipyard had to expand some of its areas due to the new mix, such as documentation control, engineering analysis and weight control for the increased requirements imposed by government work.

1. Computer Aided Design

Shipyard M uses CADAM to prepare contract plans (e.g., machinery and general arrangements) as part of its normal procedure in precontract design. Some of the precontract design tasks include, naval architecture calculations, basic ship configuration and estimating. The contract design brings in the use of SPADES, weight control and other computer assisted engineering tools, ship specification, and detailed estimates. A preliminary work breakdown is decided upon in support of the mister planning effort within the company's work breakdown structure (WBS). Review of the work and product breakdown can produce revisions and modifications to the design, as well as to the master plan. Once the contract award has been finalized then the ship configuration is set and detailed design can ensue. This involves hull fairing detailed development all the way through to lofting as well as setting up production controls for the remainder of the work.

As mentioned earlier CADAM and SPADES are well interfaced. In fact SPADES is the starting point from which CADAM can extract geometric data for detailed drawings. They have 21 graphic terminals, 19 of which are devoted to CADAM and 2 of which are for SPADES. The reason the flow of information can go from SPADES to CADAM is because loading of the SPADES data base precedes working drawing preparation using CADAM. SPADES data is used in CADAM as the starting point for structural detail drawings, as well as for backgrounds for master composites, piping, ventilating and electrical detail drawings. They have had SPADES in use for nine years and later added CADAM, which has now been in use for 2-1/2 years.

2. Computer Assisted Engineering Analysis

For hydrostatic analysis they utilize SPADES and some in-house programs. For structural analysis they use again some in-house programs and a Control Data Corporation (CDC) package for finite element type analysis. They also use a CDC package as well as an ABS package for vibrational analysis.

3. N/C Process Control

SPADES again is the primary tool for NC process control beginning with the lofting for plate cutting and frame bending. They have a Kongsberg lofting/drafting table for tape verification purposes and in addition to plate-cutting equipment, they also have N/C machine tools in their machine shop and sheet metal shop, which are programmed using Numeridex tape preparation systems.

4. Manufacturing Technologies

SPADES is utilized for the lofting function and a package called MOST has been used for time standard generation. This is one of the few shipyards that actually is involved with computer assisted time standards but they are currently only using the system for their sheet metal shop.

5. Compuer Assisted Management Systems

It is important to understand the experience of management at Shipyard M in relation to management systems. In the 1970's, due to a lack of production (labor and materials) status visibility, they invested significant resources- in developing computer-based systems to support materials requirements definition, requisitioning, purchasing, and inventory controls; production planning and control, and production labor budgeting and reporting. These systems are in use today accessed by some 190 terminals located throughout the yard.

Because of the computer systems development and data management technology used for these systems (and in fact most systems in the early and mid-70's), they are subject to extensive maintenance overhead. Additions and interfaces have proven hard to implement, and take a lot of time and effort (i.e., cost).

As a result, management now looks very critically at new systems proposals, particularly in this period of heavy competition and the critical importance of controlling overhead costs.

With the background in mind, it is time to review the systems that they do have and also examine the future plans of Shipyard M. This shipyard's non-financial management systems consist of a materials requisitioning and inventory control system for all nonspecification materials which makes use of a coded parts catalog containing some 56,000 parts, a separate but integrated (with the inventory subsystem) steel requirements system, a specification materials tracking system, a production labor management system, and an engineering project scheduling and control system.

The nonspecification-materials system is used to record engineering bill of materials requirements by drawing. Once the production bill of materials has been defined and scheduled for fabrication, assembly and installation, the shop order system is executed to generate shop orders for all production activities scheduled to complete within a moving window of the production schedule. This same system supports the withdrawal of materials from inventory for all authorized work. Material withdrawal tickets are issued by the computer for each line item of shop order material requirements which are available in inventory and called out in the engineering bill of material as taken off of the applicable working drawing. Inventory files are updated on-line when these tickets are presented to the warehouse for withdrawal.

The specification material tracking system is an on-line system which maintains scheduled and actual dates for purchase specifications, inquiry, purchase-order placement, receipt of vendor-furnished information, release for manufacture, and material receipt.

The production labor management system is used to maintain and report work package dates, budgets and status in terms of actual cost of work performed, budgeted cost of work performed, budgeted cost of work scheduled, and cost and schedule variances. This system provides summarizing reports by production organization, particular work area, trade class, and cost number/cost group.

The engineering project management system provides capabilities similar to the production labor management system and, in addition, provides a task networking facility which allows task precedence to be recorded, which is then used as a constraint in manpower leveling studies.

Planning is somewhat impaired by the fact that there is no real concept of shop or shipyard capacities, so they basically produce detail schedules assuming an infinite loading environment. The actual production departments and the planning department have a bit of anomosity in regards to each other. This has also been indicated on several of the other shipyard visits. This usually indicates that there is a poor communication link between the planning groups and the production groups which therefore inhibits the kind of feedback necessary to make planning more accurate. One suggestion made at this shipyard visit was that planning possibly drives its scheduling endeavor down into too much detail, which could perhaps be better generated by the production departments of the shipyard. For example, advance planning would handle the master scheduling and set overall objectives whereas the detail planning or process planning would be handled at the production control level.

Shipyard M's future plans include what they call a schedule integrater that would take many of their in-house systems and combine them by interfaces and pre- and post-processors into a unified system. One result of this would be that master planning would be involved in a networking system which would follow pre-established precedences and that all schedules would have some interaction with each other. In keeping with the outfit planning direction they plan to go to a pallet definition and control approach which is essentially management via work package all the way through to production. They also plan to provide an enhanced purchasing system. The overall objectives of their future plans will be to define early on all their material requirements, produce work package of roughly equal time duration, go away from the system production to more of an outfit assembly structure, eliminate the duplication in their systems, and enhance more design analysis.

Observation suggests that the plan they are pursuing, the move to more outfit planning, will be most beneficial to them. They are beginning with a full analysis of where they are currently. Then based on the deficiencies of the current system and the requirements of the outfit planning approach, they will propose where they would like to be. And then finally, they will be working out a detailed plan in which to achieve their desired results. This approach is very methodical and well-planned, and should keep them away from the problems they ran into in the 70's with management information systems.

6. Automation

Shipyard M has worked on some automation-type products but nothing which is curently affecting their production. They have demonstrated the ability to produce elaborate technology-based systems for production, but their current emphasis is away from those particular kinds of applications.

7. Summary

Shipyard M is moving in a direction which will commit them to utilizing outfit-planning techniques. There is currently no clear overall approach to management information systems, but their future plans of a work package tracking and schedule integrator seems to be a step in the right direction. Shipyard M's current approach promises to be very good if they do not allow their procedures to be circumvented as they have been in the past. A good first step to future improvement is a thorough evaluation of current systems and operating procedures, and theirs seems to be the most serious effort observed.

SHIPYARD N

Shipyard N is a large non-union shipbuilding company. They have a heavy emphasis on computer technology implementation in the design drafting and engineering area as well as the production engineering and lofting categories. There are not many implementations in production planning and control nor the actual activities of ship construction and shop work. In their future plans, planning and production control as well as outfit production are included.

Shipyard N operates on a 3-shift basis and views the way they handle their computer processing activities in a shift-wise manner. The first shift operates in a pretty much even distribution of computer-aided design, computer-aided engineering analysis, NC process control, manufacturing technologies, and computer management systems. On the second shift computer technologies are 100% data processing including data entry and running batch programs. The third shift operates roughly on 3 levels, computer-aided design, manufacturing technologies and numerical control and the computer-aided management systems. It is not uncommon for a heavy data processing effort in the second shift of an operation, however, it does serve to emphasize the unfortunate circumstance of having to enter data manually into the computer.

1. Computer-Aided Design

Shipyard N is a fairly heavy user of computer aided design. Their piping is done in a 3-D engineering mode, I believe using SPADES and all other engineering disciplines use a 2-dimensional drafting system, CADAM. Shipyard N uses SPADES for computer aided hull definition, computer aided hull fairing, parts definition, and for interactive graphics. Since they do most of their drafting with CADAM they do have an interface which will extract information out of SPADES, but this is not true going the opposite direction.

With CADAM, Shipyard N takes their structural arrangement plans and converts those into units or packaged units. They also design in a unit fashion the quarters (accommodations) and do composite work using CADAM. In fact they apply it to most of their work except the engine room. Piping arrangement are converted into 3-D piping models to validate their arrangements. Shipyard N plans in terms of two different types of units, first the package unit, which consists of onland construction and secondly the ship units which consists of onboard outfitting.

They use the COPICS program in the pipe shop for planning of personnel, material and control of material. This is currently their only application of bill of materials generation and they are not totally satisfied with the results of COPICS in this application. As shipyard N explains, COPICS has many good features but it also it has a lot of things that are unnecessary for shipbuilding which greatly ties up the computer. In other words, for their purposes COPICS represents a system hog. For example, its not too useful for them to use the sales forecasting part of the program at all. This and many other functions that are not required cannot be by-passed while running COPICS and even though these ancillary information are not printed out they still required a geat deal of computer time to calculate. Even though it has its draw-backs it has given them the flexibility to schedule by man, by craft, by package unit (work order) and/or work units, as well as status reporting capability on a daily basis for the pipe shop. As a result of the use of computer aided design and bill of materials generation in their pipe shop they feel they have achieved a 50% reduction in cost.

2. Computer-Assisted Engineering Analysis

Shipyard N has available a MarAd package for heat transfer analysis, SPADES for hydrostatic analysis, and STRUDL for McAUTO for structural and vibrational analysis. They feel that they have addressed their engineering needs adequately as far as computer technologies are concerned and are not expecting any immediate future expansion into these areas.

3. N/C Process Control

Other than the use of COPICS and CADAM for their N/C pipe bending they use SPADES for generating N/C cutting, frame bending, programming, shell plate development, and tape verification. This of course is applied to steel plate primarily and is an integral part of the lofting function.

4. Manufacturing Technologies

Shipyard N has interpreted manufacturing technologies to be roughly parallel to the N/C process control in the sense of utilizing SPADES in the lofting function. This is not uncommon and in fact computer-aided lofting should probably be defined as an N/C process control for shipyards.[1] They have an inhouse system for computer aided time standard generation and, by a broad definition, rough use of group technology for calculating cost for steel plate based on a man-hours per type type code. This in-house system's primary purpose is for control/status reporting and the computer aided time standard generation aspect of it falls under the manufacturing technology category.[2] This is one of the few packages for time standard generation that is in use in the shipyard today. Their future plans for this would fall under the functions of planning and production control, such as work organization, planning and production control, and performance calculations. The group technology aspect of the package indicates whether they can use processing lanes if its plate and steel work etc. Its not an elaborate code but it is useful for their structural steel work.

5. Computer-Assisted Management Systems

Currently shipyard N plans only to have a control/status reporting system which is in-house developed. This system primarily gathers actual man-hours spent on the contract and allows them to do performance calculations based on their schedule. The useful aspect that this system offers are the computer-aided time standard ability and the group technology code for certain parts. This should allow not only for accurate performance measurements but, hopefully in the future, for more accurate measurements, work organization, production control, and scheduling. In its current form, it could be considered to be used for ship construction control and steelwork production scheduling; however, it is not a rigorous or formal system dedicated to these functions. Shipyard N claims no particular computer technology applications

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[1] In fact, this change has been made for Section 3, Software Evaluation, of this report.

[2] Time standard generation has been considered part of management systems for Section 3, the main report, also.

toward facility planning, material requirements planning, PERT/CPM, planning systems, production crew assignment/loading, quality assurance, and/or scheduling systems. No near term work is indicated in these areas.

Currently they are estimating procedure involving two types of estimates, production estimates and engineering estimates. Engineering estimates involve the initial bid as well as final cost allocation after award of a contract, in terms of dollars and materials. Production estimates are based totally on hours and once divided out establish the work order budgets. Currently this is done manually with the intent on providing some computer assistance the ability to look up historical information.

Also recall that the pipe shop is using COPICS in a of the way management control capacity. Refer to Section 1, Computer Aided Design for further discussion on this aspect.

6. Automation

Shipyard indicates there is no automation at this time and no future plan within the next five years.

7. summary

Shipyard N believes they have gained a 35% productivity improvement in the last 3 years by implementing outfit planning methods and obtaining better utilization out of their computer technologies (most of which have been there for more than 3 years). More specifically they believe they have had a 50% reduction in the cost of operating their pipe shop, mostly due to the utilization of computer technologies such as COPICS, and their 3-D modelling system. Shipyard N has the advantage of utilizing a small number of different packages in their shipyard and thereby reducing integration problems. However there is still integration that could be improved in terms of the CADAM to SPADES interface and interface with their computer-aided engineering analysis packages.

The primary benefits observed by this yard were product quality, leadtime reduction, and several involving control, scheduling, standardization and producibility. The major problems encountered at Shipyard N were software maintenance and support, support personnel, system user friendliness, training, and the worst being integration with other systems.

SHIPYARD O

The history of applying computer technologies at Shipyard O reads something like this; in 1960 they performed lofting research but it was not until the 1970s that N/C and lofting functions were in place and operating, and now in the 1980s computer-aided engineering and computer-assisted management systems, as well as some automated research are beginning to be incorporated into their shipyards. The benefits they have received so far include reduced time in the record keeping, document handling and engineering calculations areas.

Shipyard O’s approach to implementing computer technologies into the mainstream of their engineering and scheduling functions has consisted of the establishment of a technical data center (as oppose to the data processing center). While it is true that many shipyards visited had separate departments for their computer technologies not as many had a separate department and a separate computer facility. The thrust of the technical data center concept was to get middle management to familiarize themselves with the computer tools available to them on their own volition. Those that have, have become quite dependent on their computer tools to assist them in their day to day operations. However many middle managers have not taken advantage of the facility and are still resisting the turn towards computer technologies.

The technical data center approach has had varying results. Programs written by one group or department are not unified or transportable to other groups or even internally within their own group. This produces a great deal of redundant data being input into the computer by varying groups which also brings a host of data reliability questions into the picture. The technical data center systems groups has been combating these problems by working with these departments to utilize data that is already being input into the system. This does not mean that integration has been achieved, because data is still copied into the computer system in a sort of parallel fashion, however it does create a sort of quasi-standardization. It is perhaps better than making enemies in these departments by suggesting standard report generators and new systems to which the people are unaccustomed. Therefore it has accomplished its objectives to date in terms of getting several people involved in using the computer as a tool to assist them with their work.

Shipyard O seems to have adequate upper management commitment to implementing computer technologies however, it is not enough in this case. The systems group that has been implemented exists basically on its own to convince middle management to utilize its services. Middle management really does not have the incentive to do so from upper management (nor elsewhere) and the systems group does not have the authority to insist that they do. The result is that most middle managers are resisting involvement in yet another thing which would take them away from their busy day. If the upper management can put together a unified plan including the middle manager level than this shipyard could be well on the way to achieving maximum benefits from computer technologies.

Shipyard O is preparing to move into computer technology in a large way in the later 1980s. What they have accomplished up until now constitutes a learning curve. With the right upper and middle management support they could now begin to harvest the applications knowledge that they have gained and provide systems that would really assist them in overall control and improvement of their facility.

1. Computer-Aided Design

Currently their computer-aided design capabilities include ANVIL 4000 for drafting, HULDEF and AUTOKON for Hull Definition and Fairing. Their future plans suggest a total conversion to 3-D systems (which could conceivably used in the 2-D mode for engineering drafting). To date their satisfaction with their existing computer-aided design tools ranks in the medium satisfactory range and they have been in use for 2-1/2 years.

In this visit some special attention was given to the problems associated with ANVIL 4000 usage. Currently they are not using ANVIL 4000 in actual ship production though it is used for some of their in house construction work for their facilities. ANVIL 4000 has the advantage of being a hardware independent computer software package for computer-aided design. However in this case it works towards their detriment since it is not dedicated on one particular computer system. In other words because of the derands on the computer-from all users the turn-around-tire for ANVIL 4000 for design work is very slow. Another problem that sometime occurs with software vendors is they change their support requiurements and such is the case of ANVIL. They had originally supported the RAMTEK terminals for graphics and now they no longer do SO. This means that the RAMTEKs may or may not be a viable graphics terminal to use with the ANVIL package. Shipyard O seems to feel that the future may hold a different CAD package for them such as autographies or someother software package most likely with 3-D capabilities.

Shipyard O does have a way to interface ANVIL 4000 and their AUTOKON system, through the APT numerical control data file. Granted that this is a back-door approach to linking systems, it still saves time and effort when going from one system to another. Also, AUTOKON and PRELIKON (a system for preliminary engineering of ship design) are linked through a preprocessor written in GRAPL which is an AUTOKON macro language. Another labor saving device that they have performed is to do directly from their lofting information to their GERBER plotter, saving the tape generation steps performed at most shipyards. Even though these are not truely sophisticated networking techniques, the point is that they fill the immediate need and they work. This is the most important factor in their current operating environment.

2. Computer-Assisted Engineering Analysis

Currently Shipyard O has a limited number of computer-aided engineering programs and their dissatisfaction with them is prompting them to look at other systems. For hydrostatic analysis they are using PRELIKON and SHCP with some in-house modifications. Once again these are linked to the AUTOKON and ANVIL packages when the need be. Structural and vibrational analysis is carried out visa STRUDL with no in-house modifications. They have been using STRUDL on a time-share basis for one year. Communications between O's computer and CDC are still not totally satisfactory.

3. N/C Process Control

Shipyard O utilizes familiar plate cutting techniques utilizing oxy-acetylene-type machines based on their lofting tapes. In the visit, they highlighted one of their numerical control processing applications which exemplifies some very good characteristics. A W. A. Whitney panel master machine is providing them with a high return on investment and productivity improvement per the following sheet. Their employees were involved in the selection of the machine, and this is one of the things that makes it work so well. It was apparent that there was a greal deal of enthusiasm on the part of the operator. This kind of enthusiasm can make even a mediocre system work acceptably well, whereas a negative attitude on the part of the employees can make an acceptional machine work fairly poor.

W. A. Whitney - Model #647C
N/C Panel Master Machine

PRODUCTION COMPARISON CHART

Part Name	Type of Material	Hours	Quan. on Machine	Quan. by Hand
Flex Connection	.250 Aluminum	6	22	3
Flanges	.250 Mild Steel	8	48	4
Fan Foundation	.375 Mild Steel	6	10	1.5
Stanchion Parts	.250 Stainless Steel	2	66	5
Vent Hangers	.125 Aluminum	8	600	14
Electrical Stowage Shelves	.187 Mild Steel	8	32	1
Strainer Plate	.375 Mild Steel	1	3	It takes 24 hours to fab one (1) strainer plate by hand

4. Manufacturing Technologies

Shipyard O currently is not involved with manufacturing technologies as defined by the survey other than normal lofting procedures.

5. Computer Assisted Management Systems

Current scheduling is performed by ship as opposed to by drawing number. Each craft is responsible for their own procurement and one craft. will not work in tandem with other crafts on a given work order. Currently there is not a precise scheduling point based system. Their schedule is driven primarily by the lead men on repeat ships. Planners are not really sequence oriented because the learning curve effect of the actual production is not being transmitted back up stream to the planners. Observation suggests that this is not because of a strict top down management system but more or less a matter of human factor issues between the planners and the production people, though this is not substantiated. The computer systems people are sort of in the middle of this battle and does not seem appropriate for them to suggest a solution until the human factors side is resolved.

Currently Shipyard O has a loosely based computer assisted management system but they feel that it covers most of the control on scheduling areas. They have written most of their in-house scheduling and control systems through the use of VISION and INFO. INFO is a very high level language for data base management and allows programming to be done even by non-programmers (even thought Some training in INFO is required). VISION is a sophisticated interactive scheduling system which handles large networks and uses INFO as its report writter. This approach has allowed them to get systems up and running quickly, however, with each group writting their own programs this produced the integration problems mentioned at the onset of this summary. Trying to create a subliminal structure to parallel independent manager's programs is possible and the systems group is doing some of thati; however, it is not an optimal approach. Again this stems from the lack of middle management support for systems analysis. This takes on few forms, first the managers are too busy to be trained themselves so they send their younger employees to be trained and then secondly, once the younger employees are trained the middle managers stiffled their ideas for job security reasons. This is not unique to Shipyard O however, the interveiw did afford the chance to investigate the problem a little more in depth and that's why its been discussed in such detail so far.

In the future the use of RIM, Reational Information Manager, is planned be used as a powerful report generator which will satisfy naval reporting requirements.

6. Automation

Currently the Cincinnati T-3 robot is being investigated for welding applications. The preliminary results say that there won't be a payoff until vision systems are refined and/or offline programming is developed further. Even under these conditions the expense of such systems may be prohibitive. However in the mean time their Cincinnati T-3 is being put to full use for very limited repetitive work, and is returning some productivity improvement and labor savings in return. Since they have it, they might as well use it to its fullest extent so that they can become familiar with the technology.

7 Summary

The state of Shipyard O applications show tremendous potential for future implementation of sophisticated systems. One could suggest that they have just been through the learning curve up until this point in time. They have gone through the learning curve without any major irreversible commitments and they are now in a position to capitalize on that if they can pull it all together. They have demonstrated a tremendous programming payoff of using a data base management system query language for programming (INFO) and a similar macro scheduling language (VISION). Deriving their inhouse systems from these have been useful as a learning curve tool, however observations suggests that they should commit to a more "permanent" solution for their computer assisted management systems.

Unlike the attitude at many shipyards, Shipyard O feels that training is not a problem but more that human factors issues are. In other words, if the people at the shipyard have the will to learn these computer tools there is really no problem on teaching it to them. They have quietly squeezed computer technologies into their operations. At this point probably need to make a central plan which would involve middle managers and unify their overall approach. As they have said in a paper presented at the IREAPS symposium, three areas require particular care and integration. "These are materials management and procurement, production progress tracking, and engineering configuration and change control and these were the first to receive their attention."

SHIPYARD P

Shipyard P is a repair yard and not involved in new ship construction. Their manufacturing shop operation are second to none in terms of shop control and N/C usage relative to the other shipyards visited on this survey. Their overall use of computer technology is average compared to the other surveyed yards. Outside of their shop operations the computer aided management systems seem to be very weak and usually serves as a record keeping function.

The observations recorded in this trip summary will be biased towards the shop since an overall tour of the shipyard was not provided. Therefore this summary represents the shop activities unless otherwise stated.

1. Computer Aided Design

Shipyard P's primary emphasis is on unit part definition for overhaul and repair of ships. They also design component assemblies and do some structural work. They have applied unigraphics to most computer aided design functions for an average of five years and they rank it as medium successful (seven out of ten). Observations suggests that this is a very appropriate package for them to use given their work load. Unigraphics strength lies in its power to go from its design directly to N/C machining language or tape using the APT language. Unigraphics is more a part definition design system then a conceptual or preliminary design system. It could be said that what AUTOKON did for lofting and fairing, Unigraphics did for part and component part to N/C tape generation. They currently have about 11 terminals by which to access the computer aided design system. They estimate that the terminals are busy in productive work about 100% of the time based on a seven-hour day. They have documented a 1.5 to 1 (computer assist vs. manual) for drafting their initial drawings on the CAD system and find a 10 to 1 productivity gain any time a revision needs to be made (which is often). Often in repair work the initial input to the system is nonproductive because the designers are simply copying original ship blueprints, however, changes and modifications are inevitable and therefore make up for this inconvenience. Once deeply into the rework process they will somtimes design unique and/or new component parts as well.

2. Computer Assiged Engineering Analysis

The survey indicates the use of STRUDL for structural and DYNAL for vibrational analysis though they can access most Navy and MarAd programs through their data network. Observations suggest that the actual usage of computer aided engineering packages is not extensive, but cyclical due to the nature of the work. Not nearly as much engineering analysis is required for normal repair and overhaul operations (vs. new ship construction) since the objective is to match or exceed the replaced part's specifications. However, new systems are added during overhauls and computer analysis has contributed to obtaining reliable installations.

3. N/C Process Control

As mentioned at the on set of this summary N/C is definitely shipyard P's strong area. They carry out their shop and computer usage tracking to the nth degree. In otherwords, they are monitoring just about every aspect of usage for their N/C machines as well as their CAD system, almost to the point of overkill. This type of control at the shop level gives them a great deal of accuracy in their planning and time estimates for rework. Their N/C machines range from 5-axis mills to 3-axis machining centers to retrofited manual machines. They also have automated sheet metal equipment and utilize that for ventilation and duct work as much as possible.

They have CAD terminals in their main engineering offices but they also have several in the office nearby the shop floor. Terminals are used for the design though most adjacent to the shop are used for cutting path development and are available to designers. Since the designers and the N/C part programmers are working very closely togehther an informal feedback system results whose main effect is to improve the producibility of designs. The Unigraphics data base is available through the distributed terminal network to all users and also enhances communications.

A very revealing statistic is noted in some of their documentation regarding the number of repeat jobs that they have through their shop. An average of 60% of their N/C work is repeat jobs. Not only does this reinforce the justification for N/C usage it also provides a chal-lenge to many-shipbuilders who have not justified N/C in their shops because they claim to only do one-of-a-kind work. Shipyard P has an advantage in justifying N/C as compared to other shipbuilders, however, - in that their shop activities appear to be one of the busiest parts of their shipyard as opposed to new ship construction in which it can be 200% busy one week and 20% busy the next.

Note: Indepth tracking of machine utilization is an excellent way to have tight control of shop operations, however it also provides the information needed to justify newer equipment or stronger preventative maintenance programs, etc.

4. Manufacturing Technologies

Shipyard P uses Unigraphics for their lofting, however they have some inhouse program for parts nesting and process planning. Parts nesting is primarily a manual operation however once it has been performed on a component part or assembly that nest can be saved for future use. Process planning operates on a similar mode since they keep an elaborate N/C tape library and when the parts come up again they will be machined in the exact way they were before.

5. Computer Assisted Management Systems

Computer assisted management systems are a sore spot for Shipyard P. Their management-information system is currently done on a 100% batch mode operation. It does not directly tie in to the shop tracking systems and observations suggests that it is more a record keeping kind of function than it is a management information tool. Separately, the shop CAM Group and design sets up elaborate forecast of manpower and machine utilization usually for an entire year ahead. This forecast provides them with the information needed to discuss schedule impact for unexpected work as well as for emergency jobs.

Plannning and scheduling are done separately at Shipyard P. Planning is responsible for estimating cost, materials, and specifications for a given job. Planning makes rough-schedule estimates for these jobs, but primarily come up with a scope of work and an estimate, and finally pull together what would be considered the work package. Scheduling then fits the packages into the main stream of their operations. However, the N/C shop scheduling is a separate entitity not only from the planning function but also from the other shops. It seems as though shipyard planners are not fully in the loop, at least information-wise, to make accurate scheduling decisions.

The material system at Shipyard P is marginal at best. Steps are being taken to improve this system because of its inaccuracies. A material requirements planning system is currently being implemented to try and remedy this situation.

Future plans promise to provide a real-time managment system. The specifications call for linkage between material and PERT type or CPM functions and the drawing schedule. By this they hope to come up with more accurate job material lists and procurement schedules, more realistic production schedules, and some control over design/drafting time.

6. Automation

There is no automation currently underway nor specifically planned for in the future.

7. summary

Shipyard P is very well set for job shop and fabrication shop operations relating to repair and overhaul work. Their management information system is not currently too useful; however, the future system promises to be more appropriate. Their designers and manufacturing planners in the shops seem to be working well together. It seems as though it would be a useful to have their overall shipyard scheduling and planning functions work more closely together and tie those in with the N/C shop's control capabilities.

SHIPYARD S

The Grumman SP-4 software tool project and the IITRI CAD/CAM survey were fortunate to spend the total of about 4 hours on this particular shipyard visit. Due to circumstances beyond their control we had to conduct the interviews in a very quick fashion. Shipyard S had promised to fill out a questionnaire for the CAD/CAM survey project but have not done so. So for the purposes of this summary, the interviewing team has made an attempt to fill one out for them though it is not part of the statistical survey report. However, the net effect is that this summary will not be nearly as accurate as the other shipyard summaries.

Shipyard S feels that it has gone a long way toward implementing zone outfitting planning concepts and method. Though in terms of computer technology they fall in as a medium user, meaning they are not at the lowest end of computer application but they seem to be far short of the heaviest computer technology user. In the period before 1972, Shipyard S produced ships in much the traditional system's fashion: providing detailed designs by functional system and the production function very simply organized. In the period from '72 to '83, their detailed design became more elaborate involving not only systems engineering but also a composite check for interferences by zone. Production planning was introduced in a zone-wise manner and then construction was conducted in a macro zone concept. The plans for the future involve a transition design step which will move the zone outfitting concept up into the design level, uniting design and planning into one group and then going back to a basic production function which will work exclusively in terms of the zones.

The reason for not applying a great deal of computer technologies to this point in time is that they do not want to computerize a rapidly changing process. The method, manual approach to outfit planning needs to develop further before they design a computer system to support it. However, a slightly contradictory point of view was observed when they mentioned that they did not believe in an integrated data base concept. In other words, systems should be able to stand on their own to perform their own functions and presumably be tapped when necessary by some master system. If this were the case then shipyards could have proceeded with certain aspects of their automation of outfit planning and elsewhere to be tapped by a master system in the future. At any rate, they have felt that the waiting game is a luxury that they can afford for now. It is not as though they have been totally slack; however, they do have some of the standard packages primarily in their engineering analysis and procurement methods. In fact, when they get into the development and implementation of systems, it seems as though they do a very thorough job, the bottom line being that it works right. One example of this is their in-house material control system which has between 80,000 and 200,000 parts coded into it and which provides them with a tool they can use for procurement, and in design to specify material usage.

1. Computer-Aided Design

Their computer support to design is primarily through the AUTOKON system through which they do hull definition and fairing. Also, their material control system is involved in the bill of materials generation up front in the design process. The design of the system is such that it provides a rough "group technology" type system by which to access parts within that data base.

2. **Computer-Assisted Engineering Analysis**

The interview did not provide an in-depth discussion on Shipyard S's computer-engineering analysis tools but, in addition to the analytical capabilities of AUTOKON, they are presumed to have some of the standard analysis capabilities such as hydrostatic and hydrodynamic analysis, as well as structural and possibly vibrational analysis.

3. N/C Process Control

Shipyard S has the capability of most shipyards in cutting steel plate. They plan to implement automated N/C pipe bending equipment in the future.

4. **Manufacturing Technologies**

Nothing here except the ability for computer aided lofting and parts nesting through the AUTOKON system.

5. Computer-Assisted Management Systems

Observations suggests that Shipyard S is less assisted by computer technologies in the management area than most shipyards interviewed. It is reasonable to believe that they do have the normal accounting system by which to do high-level project management, and such a record keeping function would be expected; however, there is no indication of computer support to planning or scheduling systems. The exception to this is their material control system which is quite elaborate and provides most material information except real-time statusing for shop floor control.

The material control system consists of major commodity categories which are further broken down by class and by item. All in all, this system provides a unique code to each individual part, and can be accessed via catalog or in an on-line fashion to find a part definition. What this means is all their parts are conveniently accessible and they are only itemized in one place. They also have the added ability to put preference codes on those materials that they desire or want to induce designers to implement. The material control system serves a two-fold function in that designers can use it in their drawings, providing independent parts codes (as opposed to unique part line-item numbers based on the drawing as it is done in most companies) which later saves procurement a great deal of effort (in terms of speaking the same language) by communicating exactly which part is called for. It also enables the designers to work at a detailed level from the very beginning in the sense that they can design around real parts and parts that are preferred for use by the shipyard.

6. Automation

No automation was observed or mentioned in the visit.

7. Summary

Shipyard S's conservative approach to computerization is exemplified when they do a first ship. They operate in a fairly manual mode until the second ship, and then it will be put on the AUTOKON data base (a software package they have used for 10 years). They have future plans for possibly implementing a 3-D graphics package, as well as possibly some other packages to use both in structural and outfit planning. Though much of the interviewing time was spent talking about their future plans, where they are now is a good example of accomplishing things without computer technologies. They have a fairly good track record on implementing zone-outfitting techniques and coming in below cost and ahead of schedule without a heavy emphasis on computer technologies. However, they realize the importantance of computer applications in the 80's and exhibit a great deal of planning in that direction.

A P P E N D I X   D

SHIPYARD FUNCTIONAL AREAS
RELEVANT TO THE CAD/CAM
SURVEY

PART I: COMPUTER TECHNOLOGIES AND SHIPBUILDING FUNCTIONS

For each of the shipbuilding functions listed below, please indicate which are aided at your yard by one of the six computer technology areas described using the following rating system in indicating your applications:

- \+ = Successful Application
- ✓ = Satisfactory Application
- \- = Unsatisfactory Application
- N = New Application
- F = Application Planned for Future Implementation

For example, if your organization is very satisfied with its application of interactive graphics to "hull form definition and analysis", a "+" would appear under Column I on Line 1.

CODE	SHIPBUILDING FUNCTIONS	COMPUTER TECHNOLOGY AREAS: I. Computer Aided Design	II. Computer Aided Engineering Analysis	III. N/C Process Control	IV. Manufacturing Technologies	V. Computer Assisted Management Systems	VI. Automation
	A1. Design, Drafting, and Engineering						
1.	Hull Form Def. & Analysis						
2.	Parts Definition:						
3.	Mechanical/Structural						
4.	Electrical						
5.	Piping						
6.	Outfitting/accommodations						
7.	Shop Drawing Generation						
8.	Specification Sheet Generation						
9.	Parts Coding						
10.	Parts Listing						
11.	Matl. Requirements Definition						
12.	Production System Engineering						
13.	Analysis:						
14.	Area/Volume						
15.	Clearances/Interferences						
16.	Structural						
17.	Other Analysis						
18.	Modeling:						
19.	Mathematical						
20.	Geometric						
	A2. Production Engineering and Lofting						
21.	Parts Nesting						
22.	Fabrication Detail Generation						
23.	Cutting Path Development						
24.	Dimensional & Quality Control						
25.	Hull Fairing:						
26.	Lofting						
27.	Process Engineering						
	B. Planning and Production Control						
28.	Work Organization						
29.	Contract Scheduling						
30.	Steelwork Production Scheduling						
31.	Outfit Production Scheduling						
32.	Outfit Installation Scheduling						
33.	Ship Construction Scheduling						
34.	Steelwork Production Control						
35.	Outfit Production Control						
36.	Outfit Installation Control						
37.	Ship Construction Control						
38.	Inventory Control						
39.	Quality Control						
40.	Personnel Scheduling						
41.	Performance Calculations						
42.	Purchasing						
43.	Estimating						
44.	Facilities Planning						
45.	Material Flow						
46.	Material Handling						
	C. Steelwork Production						
47.	Stockyard & Treatment						
48.	Cutting						
49.	Forming						
50.	Subassembly						
51.	Structural Unit Assembly						
52.	Outfit Steelwork						
	D. Manufacturing and Production Activities						
53.	Pipework						
54.	Engineering/Machine Shop						
55.	Blacksmith Shop						
56.	Sheetmetal Work						
57.	Woodworking/Joiner Shop						
58.	Electrical						
59.	Rigging						
60.	Maintenance						
61.	Warehousing						
	E. Pre-Erection Outfitting Activities						
62.	Outfitting						
63.	Module Building						
64.	Outfit Parts Marshalling						
65.	Pre-Erection Outfitting						
66.	Block Assembly						
67.	Unit and Block Storage						
	F. Ship Constr. & Installation						
68.	Ship Construction						
69.	Hull Erection and Fairing						
70.	Welding						
71.	Staging and Access						
72.	Pipework						
73.	Engine Room Machinery						
74.	Hull Engineering						
75.	Sheetmetal Work Installation						
76.	Woodwork Installation						
77.	Electrical Installation						
78.	Painting						
79.	Testing						

APPENDIX E

DESIGN AGENCY FUNCTIONAL AREAS RELEVANT TO THE CAD/CAM SURVEY

PART I: COMPUTER TECHNOLOGIES AND SHIPBUILDING FUNCTIONS

For each of the shipbuilding functions listed below, please indicate which are aided at your yard by one of the six computer technology areas described using the following rating system in indicating your applications:

- \+ = Successful Application
- ✓ = Satisfactory Application
- \- = Unsatisfactory Application
- N = New Application
- F = Application Planned for Future Implementation

For example, if your organization is very satisfied with its application of interactive graphics to "hull form definition and analysis", a "+" would appear under Column I on Line 1.

CODE	SHIPBUILDING FUNCTIONS	COMPUTER TECHNOLOGY AREAS					
		I. Computer Aided Design	II. Computer Aided Engineering Analysis	III. N/C Process Control	IV. Manufacturing Technologies	V. Computer Assisted Management Systems	VI. Automation
	A1. Design, Drafting, and Engineering						
1.	Hull Form Def. & Analysis						
2.	Parts Definition:						
3.	Mechanical/Structural						
4.	Electrical						
5.	Piping						
6.	Outfitting/accommodations						
7.	Shop Drawing Generation						
8.	Specification Sheet Generation						
9.	Parts Coding						
10.	Parts Listing						
11.	Matl. Requirements Definition						
12.	Production System Engineering						
13.	Analysis:						
14.	Area/Volume						
15.	Clearances/Interferences						
16.	Structural						
17.	Other Analysis						
18.	Modeling:						
19.	Mathematical						
20.	Geometric						
	A2. Production Engineering and Lofting						
21.	Parts Nesting						
22.	Fabrication Detail Generation						
23.	Cutting Path Development						
24.	Dimensional & Quality Control						
25.	Hull Fairing:						
26.	Lofting						
27.	Process Engineering						
	B. Planning and Production Control						
28.	Work Organization						
29.	Contract Scheduling						
30.	Steelwork Production Scheduling						
31.	Outfit Production Scheduling						
32.	Outfit Installation Scheduling						
33.	Ship Construction Scheduling						
34.	Steelwork Production Control						
35.	Outfit Production Control						
36.	Outfit Installation Control						
37.	Ship Construction Control						
38.	Inventory Control						
39.	Quality Control						
40.	Personnel Scheduling						
41.	Performance Calculations						
42.	Purchasing						
43.	Estimating						
44.	Facilities Planning						
45.	Material Flow						
46.	Material Handling						

APPENDIX F

SHIPYARD QUESTIONNAIRE RESULTS

SHIPYARD QUESTIONNAIRE

RESULTS

I. COMPUTER TECHNOLOGY AND SHIPYARD FUNCTIONS

CROSS SUMMARY FOR ALL FILES OF TYPE 1

ROW NO: 1

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	5	3	1	0	0	0
CHECK:	2	5	1	0	0	0
MINUS:	0	0	0	0	0	0
NEW:	1	0	0	0	0	0
FUTURE:	5	0	0	0	0	0
BLANK:	5	10	16	18	18	18

ROW NO: 2

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	1	0	3	2	0	0
CHECK:	2	0	1	0	1	0
MINUS:	0	0	0	0	0	0
NEW:	1	0	0	0	0	0
FUTURE:	3	0	0	0	0	0
BLANK:	11	18	14	16	17	18

ROW NO: 3

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	2	5	2	2	1	0
CHECK:	6	0	1	0	0	0
MINUS:	0	0	0	0	0	0
NEW:	0	0	0	0	0	0
FUTURE:	5	2	0	0	1	1
BLANK:	5	11	15	16	16	17

ROW NO: 4

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	1	1	0	0	0	0
CHECK:	2	1	0	0	0	0
MINUS:	0	0	0	0	0	0
NEW:	1	0	0	0	0	0
FUTURE:	6	1	0	0	0	0
BLANK:	8	15	18	18	18	18

ROW NO: 5

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	1	1	0	0	0	0
CHECK:	2	3	0	0	0	0
MINUS:	0	0	0	0	0	0
NEW:	2	1	0	0	0	0
FUTURE:	6	1	1	0	0	0
BLANK:	7	12	17	18	18	18

ROW NO: 6

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	1	1	2	2	0	0
CHECK:	3	0	0	0	1	0
MINUS:	0	0	0	0	0	0
NEW:	0	0	0	0	0	0
FUTURE:	6	0	0	0	0	0
BLANK:	8	17	16	16	17	18

ROW NO: 7

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	2	0	3	1	1	0
CHECK:	2	1	2	0	1	0
MINUS:	0	0	0	0	0	0
NEW:	1	0	0	0	0	0

FUTURE:	5	FUTURE:	1	FUTURE:	0	FUTURE:	2	FUTURE:	0	FUTURE:	0
BLANK:	8	BLANK:	16	BLANK:	13	BLANK:	15	BLANK:	16	BLANK:	18

ROW NO: 8

PLUS:	1	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	1	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	3	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	13	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	18

ROW NO: 9

PLUS:	2	PLUS:	0	PLUS:	2	PLUS:	0	PLUS:	2	PLUS:	0
CHECK:	2	CHECK:	0	CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	1	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	4	FUTURE:	0	FUTURE:	1	FUTURE:	0	FUTURE:	1	FUTURE:	0
BLANK:	9	BLANK:	18	BLANK:	14	BLANK:	18	BLANK:	15	BLANK:	18

ROW NO:10

PLUS:	0	PLUS:	0	PLUS:	3	PLUS:	1	PLUS:	4	PLUS:	0
CHECK:	4	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	1	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	3	FUTURE:	0	FUTURE:	1	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	10	BLANK:	18	BLANK:	14	BLANK:	17	BLANK:	13	BLANK:	18

ROW NO:11

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	2	PLUS:	0
CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	2	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	3	FUTURE:	0
BLANK:	15	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	13	BLANK:	18

ROW NO:12

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0
CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	2	FUTURE:	1	FUTURE:	0	FUTURE:	0	FUTURE:	1	FUTURE:	0
BLANK:	15	BLANK:	17	BLANK:	18	BLANK:	18	BLANK:	16	BLANK:	18

ROW NO:13

PLUS:	0	PLUS:	1	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	2	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	1	FUTURE:	2	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	15	BLANK:	15	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	18

ROW NO:14

PLUS:	4	PLUS:	4	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	1	CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	1	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	2	FUTURE:	2	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0

```
BLANK: 11   BLANK: 10   BLANK: 18   BLANK: 18   BLANK: 18   BLANK: 18

ROW NO:15
---------
PLUS:    2  PLUS:    1  PLUS:    0  PLUS:    0  PLUS:    0  PLUS:    0
CHECK:   1  CHECK:   0  CHECK:   0  CHECK:   0  CHECK:   0  CHECK:   0
MINUS:   0  MINUS:   0  MINUS:   0  MINUS:   0  MINUS:   0  MINUS:   0
NEW:     0  NEW:     1  NEW:     0  NEW:     0  NEW:     0  NEW:     0
FUTURE:  4  FUTURE:  4  FUTURE:  0  FUTURE:  0  FUTURE:  0  FUTURE:  0
BLANK:  11  BLANK:  12  BLANK:  18  BLANK:  18  BLANK:  18  BLANK:  18

ROW NO:16
---------
PLUS:    4  PLUS:    5  PLUS:    0  PLUS:    0  PLUS:    0  PLUS:    0
CHECK:   1  CHECK:   3  CHECK:   1  CHECK:   0  CHECK:   0  CHECK:   0
MINUS:   0  MINUS:   0  MINUS:   0  MINUS:   0  MINUS:   0  MINUS:   0
NEW:     0  NEW:     0  NEW:     0  NEW:     0  NEW:     0  NEW:     0
FUTURE:  1  FUTURE:  2  FUTURE:  0  FUTURE:  0  FUTURE:  0  FUTURE:  0
BLANK:  12  BLANK:   8  BLANK:  17  BLANK:  18  BLANK:  18  BLANK:  18

ROW NO:17
---------
PLUS:    3  PLUS:    5  PLUS:    0  PLUS:    0  PLUS:    0  PLUS:    0
CHECK:   1  CHECK:   2  CHECK:   0  CHECK:   0  CHECK:   1  CHECK:   0
MINUS:   0  MINUS:   0  MINUS:   0  MINUS:   0  MINUS:   0  MINUS:   0
NEW:     0  NEW:     0  NEW:     0  NEW:     0  NEW:     0  NEW:     0
FUTURE:  1  FUTURE:  1  FUTURE:  0  FUTURE:  0  FUTURE:  0  FUTURE:  0
BLANK:  13  BLANK:  10  BLANK:  18  BLANK:  18  BLANK:  17  BLANK:  18

ROW NO:18
---------
PLUS:    0  PLUS:    0  PLUS:    0  PLUS:    0  PLUS:    0  PLUS:    0
CHECK:   0  CHECK:   1  CHECK:   0  CHECK:   0  CHECK:   0  CHECK:   0
MINUS:   0  MINUS:   0  MINUS:   0  MINUS:   0  MINUS:   0  MINUS:   0
NEW:     0  NEW:     0  NEW:     0  NEW:     0  NEW:     0  NEW:     0
FUTURE:  0  FUTURE:  1  FUTURE:  0  FUTURE:  0  FUTURE:  0  FUTURE:  0
BLANK:  18  BLANK:  16  BLANK:  18  BLANK:  18  BLANK:  18  BLANK:  18

ROW NO:19
---------
PLUS:    2  PLUS:    2  PLUS:    0  PLUS:    0  PLUS:    0  PLUS:    0
CHECK:   0  CHECK:   3  CHECK:   0  CHECK:   0  CHECK:   0  CHECK:   0
MINUS:   1  MINUS:   0  MINUS:   0  MINUS:   0  MINUS:   0  MINUS:   0
NEW:     1  NEW:     0  NEW:     0  NEW:     0  NEW:     0  NEW:     0
FUTURE:  1  FUTURE:  1  FUTURE:  0  FUTURE:  0  FUTURE:  0  FUTURE:  0
BLANK:  13  BLANK:  12  BLANK:  18  BLANK:  18  BLANK:  18  BLANK:  18

ROW NO:20
---------
PLUS:    3  PLUS:    2  PLUS:    0  PLUS:    0  PLUS:    0  PLUS:    0
CHECK:   2  CHECK:   3  CHECK:   1  CHECK:   1  CHECK:   0  CHECK:   0
MINUS:   0  MINUS:   0  MINUS:   0  MINUS:   0  MINUS:   0  MINUS:   0
NEW:     1  NEW:     0  NEW:     0  NEW:     0  NEW:     0  NEW:     0
FUTURE:  2  FUTURE:  1  FUTURE:  0  FUTURE:  0  FUTURE:  0  FUTURE:  0
BLANK:  10  BLANK:  12  BLANK:  17  BLANK:  17  BLANK:  18  BLANK:  18

ROW NO:21
---------
PLUS:    4  PLUS:    1  PLUS:    2  PLUS:    5  PLUS:    1  PLUS:    0
CHECK:   2  CHECK:   0  CHECK:   2  CHECK:   1  CHECK:   0  CHECK:   0
MINUS:   0  MINUS:   0  MINUS:   0  MINUS:   0  MINUS:   0  MINUS:   0
NEW:     0  NEW:     1  NEW:     0  NEW:     0  NEW:     0  NEW:     0
FUTURE:  3  FUTURE:  0  FUTURE:  1  FUTURE:  0  FUTURE:  0  FUTURE:  0
            BLANK:  16  BLANK:  13  BLANK:  12  BLANK:  17  BLANK:  18
```

ROW NO:22

PLUS:	3	PLUS:	2	PLUS:	2	PLUS:	2	PLUS:	0	PLUS:	0
CHECK:	1	CHECK:	0	CHECK:	2	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	3	NEW:	1	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	2	FUTURE:	0	FUTURE:	1	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	9	BLANK:	15	BLANK:	13	BLANK:	16	BLANK:	18	BLANK:	18

ROW NO:23

PLUS:	3	PLUS:	1	PLUS:	2	PLUS:	5	PLUS:	0	PLUS:	0
CHECK:	1	CHECK:	1	CHECK:	3	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	1	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	2	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	11	BLANK:	16	BLANK:	13	BLANK:	13	BLANK:	18	BLANK:	18

ROW NO:24

PLUS:	1	PLUS:	0	PLUS:	2	PLUS:	1	PLUS:	0	PLUS:	0
CHECK:	1	CHECK:	0	CHECK:	1	CHECK:	1	CHECK:	2	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	1	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	2	FUTURE:	0	FUTURE:	1	FUTURE:	0	FUTURE:	0	FUTURE:	1
BLANK:	13	BLANK:	18	BLANK:	14	BLANK:	16	BLANK:	16	BLANK:	17

ROW NO:25

PLUS:	4	PLUS:	3	PLUS:	2	PLUS:	1	PLUS:	0	PLUS:	0
CHECK:	1	CHECK:	1	CHECK:	1	CHECK:	1	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	1	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	3	FUTURE:	1	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	10	BLANK:	12	BLANK:	15	BLANK:	16	BLANK:	18	BLANK:	18

ROW NO:26

PLUS:	3	PLUS:	1	PLUS:	5	PLUS:	5	PLUS:	1	PLUS:	0
CHECK:	2	CHECK:	3	CHECK:	3	CHECK:	2	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	1	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	3	FUTURE:	0	FUTURE:	1	FUTURE:	1	FUTURE:	0	FUTURE:	0
BLANK:	10	BLANK:	13	BLANK:	9	BLANK:	10	BLANK:	17	BLANK:	18

ROW NO:27

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	1	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	2	FUTURE:	1	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	15	BLANK:	16	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	18

ROW NO:28

PLUS:	1	PLUS:	0	PLUS:	1	PLUS:	0	PLUS:	2	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	3	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	1	FUTURE:	3	FUTURE:	0
BLANK:	17	BLANK:	18	BLANK:	17	BLANK:	17	BLANK:	10	BLANK:	18

ROW NO:29

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	3	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	3	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	2	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	5	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	5	BLANK:	18

ROW NO:30

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	4	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	3	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	1	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	4	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	17	BLANK:	6	BLANK:	18

ROW NO:31

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	3	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	4	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	1	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	4	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	6	BLANK:	18

ROW NO:32

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	3	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	3	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	1	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	4	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	7	BLANK:	18

ROW NO:33

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	4	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	4	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	1	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	3	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	6	BLANK:	18

ROW NO:34

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	3	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	2	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	1	FUTURE:	4	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	17	BLANK:	9	BLANK:	18

ROW NO:35

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	3	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	4	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	10	BLANK:	18

ROW NO 36

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	3	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	5	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	9	BLANK:	18

ROW NO:37

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	3	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	4	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	1	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	2	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	3	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	5	BLANK:	18

ROW NO:38

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	2	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	0	CHECK:	6	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	1	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	1	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	4	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	17	BLANK:	18	BLANK:	4	BLANK:	18

ROW NO:39

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	2	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	1	CHECK:	3	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	1	FUTURE:	0	FUTURE:	2	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	16	BLANK:	17	BLANK:	11	BLANK:	18

ROW NO:40

PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0	PLUS:	1	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	4	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	17	BLANK:	18	BLANK:	12	BLANK:	18

ROW NO:41

PLUS:	0	PLUS:	1	PLUS:	1	PLUS:	0	PLUS:	4	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	3	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	1	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	1	FUTURE:	2	FUTURE:	0
BLANK:	18	BLANK:	17	BLANK:	17	BLANK:	17	BLANK:	8	BLANK:	18

ROW NO:42

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	3	PLUS:	0
CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	5	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	1	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	5	FUTURE:	0
BLANK:	17	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	4	BLANK:	18

ROW NO:43

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	2	PLUS:	0
CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	4	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	1	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	5	FUTURE:	0
BLANK:	17	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	6	BLANK:	18

ROW NO:44

PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0	PLUS:	2	PLUS:	0
CHECK:	2	CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	3	FUTURE:	0
BLANK:	16	BLANK:	18	BLANK:	17	BLANK:	17	BLANK:	13	BLANK:	18

ROW NO:45

PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0	PLUS:	1	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	3	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	1	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	3	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	17	BLANK:	18	BLANK:	10	BLANK:	18

ROW NO:46

PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0	PLUS:	1	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	1
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	1	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	3	FUTURE:	1
BLANK:	18	BLANK:	18	BLANK:	17	BLANK:	18	BLANK:	12	BLANK:	16

ROW NO.47

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	2	CHECK:	2
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	1	FUTURE:	0	FUTURE:	1	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	17	BLANK:	18	BLANK:	14	BLANK:	16

ROW NO:48

PLUS:	1	PLUS:	0	PLUS:	7	PLUS:	3	PLUS:	2	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	5	CHECK:	0	CHECK:	2	CHECK:	1
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	3	FUTURE:	1	FUTURE:	0	FUTURE:	0
BLANK:	17	BLANK:	18	BLANK:	3	BLANK:	14	BLANK:	14	BLANK:	17

ROW No:49

PLUS:	0	PLUS:	0	PLUS:	3	PLUS:	1	PLUS:	1	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	1	CHECK:	2	CHECK:	1
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	1	FUTURE:	1	FUTURE:	0	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	13	BLANK:	15	BLANK:	15	BLANK:	17

ROW NO:50

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	2	PLUS:	0

CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	3	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	17	BLANK:	13	BLANK:	18

ROW NO.51

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	2	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	3	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	17	BLANK:	13	BLANK:	18

ROW NO.52

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	2	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	1	CHECK:	3	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	17	BLANK:	17	BLANK:	13	BLANK:	18

ROW NO:53

PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0	PLUS:	1	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	0	CHECK:	2	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	1	FUTURE:	1	FUTURE:	1	FUTURE:	2	FUTURE:	2	FUTURE:	0
BLANK:	17	BLANK:	17	BLANK:	15	BLANK:	16	BLANK:	13	BLANK:	18

ROW NO:54

PLUS:	0	PLUS:	0	PLUS:	3	PLUS:	0	PLUS:	1	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	2	FUTURE:	1	FUTURE:	1	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	13	BLANK:	17	BLANK:	15	BLANK:	18

ROW NO:55

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	6	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	1	FUTURE:	1	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	16	BLANK:	16	BLANK:	18

ROW NO:56

PLUS:	1	PLUS:	1	PLUS:	4	PLUS:	0	PLUS:	2	PLUS:	1
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	1	NEW:	0	NEW:	0
FUTURE:	2	FUTURE:	1	FUTURE:	2	FUTURE:	1	FUTURE:	1	FUTURE:	0
BLANK:	15	BLANK:	16	BLANK:	12	BLANK:	16	BLANK:	15	BLANK:	17

ROW NO:57

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0

MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0
NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0
FUTURE: 0	FUTURE: 0	FUTURE: 0	FUTURE: 1	FUTURE: 1	FUTURE: 0
BLANK: 18	BLANK: 18	BLANK: 18	BLANK: 17	BLANK: 16	BLANK: 18

ROW NO:58

PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 3	PLUS: 0
CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 0
MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0
NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0
FUTURE: 1	FUTURE: 2	FUTURE: 0	FUTURE: 1	FUTURE: 1	FUTURE: 0
BLANK: 17	BLANK: 16	BLANK: 18	BLANK: 17	BLANK: 14	BLANK: 18

ROW NO:59

PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 1	PLUS: 0
CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 1	CHECK: 0
MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0
NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0
FUTURE: 0	FUTURE: 0	FUTURE: 0	FUTURE: 1	FUTURE: 1	FUTURE: 0
BLANK: 18	BLANK: 18	BLANK: 18	BLANK: 17	BLANK: 15	BLANK: 18

ROW NO 60

PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 2	PLUS: 0
CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 2	CHECK: 0
MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0
NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0
FUTURE: 0	FUTURE: 0	FUTURE: 0	FUTURE: 1	FUTURE: 2	FUTURE: 0
BLANK: 18	BLANK: 18	BLANK: 18	BLANK: 17	BLANK: 12	BLANK: 18

ROW NO:61

PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 1	PLUS: 0
CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 7	CHECK: 0
MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 1	MINUS: 0
NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0
FUTURE: 0	FUTURE: 0	FUTURE: 0	FUTURE: 0	FUTURE: 2	FUTURE: 0
BLANK: 18	BLANK: 18	BLANK: 18	BLANK: 18	BLANK: 7	BLANK: 18

ROW NO:62

PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 2	PLUS: 0
CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 2	CHECK: 0
MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0
NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0
FUTURE: 0	FUTURE: 0	FUTURE: 0	FUTURE: 0	FUTURE: 0	FUTURE: 0
BLANK: 18	BLANK: 18	BLANK: 18	BLANK: 18	BLANK: 14	BLANK: 18

ROW NO:63

PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 1	PLUS: 0
CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 1	CHECK: 0
MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0
NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0
FUTURE: 0	FUTURE: 0	FUTURE: 0	FUTURE: 0	FUTURE: 1	FUTURE: 0
BLANK: 18	BLANK: 18	BLANK: 18	BLANK: 18	BLANK: 15	BLANK: 18

ROW NO:64

PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 1	PLUS: 0
CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 4	CHECK: 0
MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0

NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	1	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	12	BLANK:	18

ROW NO:65

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	2	PLUS:	0
CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	3	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	1	FUTURE:	0
BLANK:	17	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	12	BLANK:	18

ROW NO:66

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	2	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	15	BLANK:	18

ROW NO:67

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	1	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	15	BLANK:	18

ROW NO:68

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	2	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	1	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	1	FUTURE:	0
BLANK:	17	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	14	BLANK:	18

ROW NO:69

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	2	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	1	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	1	FUTURE:	0
BLANK:	17	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	14	BLANK:	18

ROW NO:70

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	1	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	1
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	1	FUTURE:	0	FUTURE:	0	FUTURE:	1	FUTURE:	2	FUTURE:	0
BLANK:	17	BLANK:	18	BLANK:	18	BLANK:	16	BLANK:	15	BLANK:	17

ROW NO:71

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0

FUTURE: 1	FUTURE: 0	FUTURE: 0	FUTURE: 1	FUTURE: 2	FUTURE: 0
BLANK: 17	BLANK: 18	BLANK: 18	BLANK: 17	BLANK: 15	BLANK: 18

ROW NO:72

PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 2	PLUS: 0
CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 1	CHECK: 0
MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0
NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0
FUTURE: 1	FUTURE: 0	FUTURE: 0	FUTURE: 1	FUTURE: 2	FUTURE: 0
BLANK: 17	BLANK: 18	BLANK: 18	BLANK: 17	BLANK: 13	BLANK: 18

ROW NO:73

PLUS: 1	PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 1	PLUS: 0
CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 1	CHECK: 0
MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0
NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0
FUTURE: 1	FUTURE: 0	FUTURE: 0	FUTURE: 1	FUTURE: 2	FUTURE: 0
BLANK: 16	BLANK: 18	BLANK: 18	BLANK: 17	BLANK: 14	BLANK: 18

ROW NO:74

PLUS: 0	PLUS: 1	PLUS: 0	PLUS: 0	PLUS: 1	PLUS: 0
CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 1	CHECK: 0
MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0
NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0
FUTURE: 2	FUTURE: 1	FUTURE: 0	FUTURE: 1	FUTURE: 2	FUTURE: 0
BLANK: 16	BLANK: 16	BLANK: 18	BLANK: 17	BLANK: 14	BLANK: 18

ROW NO:75

PLUS: 0	PLUS: 0	PLUS: 1	PLUS: 0	PLUS: 1	PLUS: 0
CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 1	CHECK: 0
MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0
NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0
FUTURE: 0	FUTURE: 0	FUTURE: 0	FUTURE: 0	FUTURE: 1	FUTURE: 0
BLANK: 18	BLANK: 18	BLANK: 17	BLANK: 18	BLANK: 15	BLANK: 18

ROW NO:76

PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 1	PLUS: 0
CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 2	CHECK: 0
MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0
NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0
FUTURE: 0	FUTURE: 0	FUTURE: 0	FUTURE: 0	FUTURE: 1	FUTURE: 0
BLANK: 18	BLANK: 18	BLANK: 18	BLANK: 18	BLANK: 14	BLANK: 18

ROW NO:77

PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 1	PLUS: 0
CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 1	CHECK: 0
MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0
NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0
FUTURE: 0	FUTURE: 0	FUTURE: 0	FUTURE: 0	FUTURE: 2	FUTURE: 0
BLANK: 18	BLANK: 18	BLANK: 18	BLANK: 18	BLANK: 14	BLANK: 18

ROW NO:78

PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 0	PLUS: 1	PLUS: 0
CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 0	CHECK: 0
MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0	MINUS: 0
NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0	NEW: 0
FUTURE: 1	FUTURE: 0	FUTURE: 0	FUTURE: 1	FUTURE: 2	FUTURE: 0

BLANK:	17	BLANK:	18	BLANK:	18	BLANK:	17	BLANK:	15	BLANK:	18

s NO. 79

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	2	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	1
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	1	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	1	FUTURE:	0
BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	18	BLANK:	14	BLANK:	17

II. SHIPYARD BENEFITS AND PROBLEMS

CROSS SUMMARY FOR ALL FILES OF TYPE 3: SECTION 1

Row		COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
ROW NO: 1	PLUS:	5	7	4	3	2	1
	CHECK:	2	3	4	3	0	0
	OHS:	1	1	1	2	2	1
	BLANK:	10	7	9	10	14	16
ROW NO: 2	PLUS:	1	1	5	3	5	1
	CHECK:	4	2	4	3	5	1
	OHS:	0	1	0	0	0	0
	BLANK:	13	14	9	12	8	16
ROW NO: 3	PLUS:	1	1	3	1	7	1
	CHECK:	1	1	2	3	3	1
	OHS:	2	1	1	1	0	0
	BLANK:	14	15	12	13	8	16
ROW NO: 4	PLUS:	2	1	3	1	7	0
	CHECK:	1	0	2	3	2	2
	OHS:	1	2	1	1	0	0
	BLANK:	14	15	12	13	9	16
ROW NO: 5	PLUS:	3	1	3	2	2	2
	CHECK:	4	1	4	3	3	0
	OHS:	0	1	0	0	1	0
	BLANK:	11	15	11	13	12	16
ROW NO: 6	PLUS:	3	1	5	3	2	1
	CHECK:	2	1	4	4	1	0
	OHS:	0	1	0	0	2	1
	BLANK:	13	15	9	11	13	16
ROW NO: 7	PLUS:	6	5	5	3	2	1
	CHECK:	0	2	4	3	2	1
	OHS:	0	0	0	0	1	0
	BLANK:	12	11	9	12	13	16
ROW NO: 8	PLUS:	1	0	1	2	4	0
	CHECK:	2	2	2	1	2	2
	OHS:	0	1	0	0	0	0
	BLANK:	15	15	15	15	12	16
9	PLUS:	0	0	0	0	2	1

CHECK:	2	CHECK:	1	CHECK:	1	CHECK:	2	CHECK:	3	CHECK:	1
OHS:	3	OHS:	2	OHS:	2	OHS:	1	OHS:	1	OHS:	0
BLANK:	13	BLANK:	15	BLANK:	15	BLANK:	15	BLANK:	12	BLANK:	16

ROW NO:10

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	6	PLUS:	0
CHECK:	2	CHECK:	0	CHECK:	1	CHECK:	1	CHECK:	4	CHECK:	0
OHS:	2	OHS:	3	OHS:	2	OHS:	1	OHS:	0	OHS:	2
BLANK:	14	BLANK:	15	BLANK:	15	BLANK:	16	BLANK:	8	BLANK:	16

ROW NO:11

PLUS:	1	PLUS:	2	PLUS:	4	PLUS:	2	PLUS:	5	PLUS:	1
CHECK:	3	CHECK:	1	CHECK:	2	CHECK:	2	CHECK:	3	CHECK:	1
OHS:	0	OHS:	1	OHS:	1	OHS:	1	OHS:	0	OHS:	0
BLANK:	14	BLANK:	14	BLANK:	11	BLANK:	13	BLANK:	10	BLANK:	16

ROW NO:12

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	1	PLUS:	1
CHECK:	2	CHECK:	0	CHECK:	2	CHECK:	1	CHECK:	1	CHECK:	1
OHS:	2	OHS:	3	OHS:	2	OHS:	1	OHS:	2	OHS:	0
BLANK:	14	BLANK:	15	BLANK:	14	BLANK:	15	BLANK:	14	BLANK:	16

ROW NO:13

PLUS:	2	PLUS:	2	PLUS:	3	PLUS:	2	PLUS:	3	PLUS:	1
CHECK:	2	CHECK:	1	CHECK:	2	CHECK:	3	CHECK:	3	CHECK:	1
OHS:	0	OHS:	1	OHS:	0	OHS:	0	OHS:	0	OHS:	0
BLANK:	14	BLANK:	14	BLANK:	13	BLANK:	13	BLANK:	12	BLANK:	16

ROW NO:14

PLUS:	3	PLUS:	1	PLUS:	3	PLUS:	1	PLUS:	4	PLUS:	2
CHECK:	1	CHECK:	1	CHECK:	1	CHECK:	2	CHECK:	2	CHECK:	0
OHS:	0	OHS:	0	OHS:	0	OHS:	1	OHS:	0	OHS:	0
BLANK:	14	BLANK:	16	BLANK:	14	BLANK:	14	BLANK:	12	BLANK:	16

ROW NO:15

PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0	PLUS:	0	PLUS:	1
CHECK:	0	CHECK:	1	CHECK:	1	CHECK:	2	CHECK:	0	CHECK:	0
OHS:	4	OHS:	2	OHS:	1	OHS:	2	OHS:	4	OHS:	1
BLANK:	14	BLANK:	15	BLANK:	15	BLANK:	14	BLANK:	14	BLANK:	16

CROSS SUMMARY FOR ALL FILES OF TYPE 3: SECTION 2

COL. #1 COL. #2 COL. #3 COL. #4 COL. #5 COL. #6

ROW NO:16

PLUS:	2	PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	1	PLUS:	1
CHECK:	3	CHECK:	5	CHECK:	6	CHECK:	5	CHECK:	6	CHECK:	0
OHS:	2	OHS:	4	OHS:	2	OHS:	0	OHS:	1	OHS:	2
BLANK:	11	BLANK:	9	BLANK:	10	BLANK:	12	BLANK:	10	BLANK:	15

ROW NO:17

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	2	CHECK:	2	CHECK:	3	CHECK:	4	CHECK:	3	CHECK:	1
OHS:	5	OHS:	5	OHS:	3	OHS:	3	OHS:	5	OHS:	2
BLANK:	11	BLANK:	11	BLANK:	12	BLANK:	11	BLANK:	10	BLANK:	15

ROW NO:18

PLUS:	0	PLUS:	1	PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0
CHECK:	2	CHECK:	0	CHECK:	1	CHECK:	4	CHECK:	6	CHECK:	1
OHS:	5	OHS:	6	OHS:	5	OHS:	3	OHS:	1	OHS:	2
BLANK:	11	BLANK:	11	BLANK:	12	BLANK:	11	BLANK:	10	BLANK:	15

ROW NO.19

PLUS:	2	PLUS:	1	PLUS:	1	PLUS:	0	PLUS:	1	PLUS:	0
CHECK:	4	CHECK:	2	CHECK:	5	CHECK:	6	CHECK:	3	CHECK:	2
OHS:	1	OHS:	4	OHS:	0	OHS:	1	OHS:	4	OHS:	1
BLANK:	11	BLANK:	11	BLANK:	12	BLANK:	11	BLANK:	10	BLANK:	15

ROW NO:20

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0
CHECK:	4	CHECK:	3	CHECK:	2	CHECK:	4	CHECK:	5	CHECK:	1
OHS:	3	OHS:	4	OHS:	4	OHS:	3	OHS:	3	OHS:	2
BLANK:	11	BLANK:	11	BLANK:	12	BLANK:	11	BLANK:	9	BLANK:	15

ROW NO:21

PLUS:	1	PLUS:	1	PLUS:	1	PLUS:	1	PLUS:	0	PLUS:	0
CHECK:	3	CHECK:	3	CHECK:	3	CHECK:	5	CHECK:	7	CHECK:	1
OHS:	2	OHS:	3	OHS:	2	OHS:	1	OHS:	1	OHS:	2
BLANK:	12	BLANK:	11	BLANK:	12	BLANK:	11	BLANK:	10	BLANK:	15

ROW NO:22

PLUS:	1	PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	1	PLUS:	0
CHECK:	2	CHECK:	6	CHECK:	3	CHECK:	5	CHECK:	5	CHECK:	2
OHS:	3	OHS:	2	OHS:	3	OHS:	1	OHS:	2	OHS:	1
BLANK:	12	BLANK:	10	BLANK:	12	BLANK:	11	BLANK:	10	BLANK:	15

ROW NO:23

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0	PLUS:	0
CHECK:	4	CHECK:	5	CHECK:	5	CHECK:	4	CHECK:	3	CHECK:	2
OHS:	2	OHS:	2	OHS:	1	OHS:	2	OHS:	5	OHS:	1
BLANK:	12	BLANK:	11	BLANK:	12	BLANK:	11	BLANK:	10	BLANK:	15

ROW NO:24

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	2	CHECK:	3	CHECK:	2	CHECK:	2	CHECK:	1	CHECK:	1
OHS:	4	OHS:	4	OHS:	3	OHS:	4	OHS:	6	OHS:	1
BLANK:	12	BLANK:	11	BLANK:	13	BLANK:	12	BLANK:	11	BLANK:	16

ROW NO:25

PLUS:	1	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	2	PLUS:	0
CHECK:	1	CHECK:	1	CHECK:	2	CHECK:	1	CHECK:	3	CHECK:	1
OHS:	4	OHS:	6	OHS:	3	OHS:	5	OHS:	4	OHS:	1
BLANK:	12	BLANK:	11	BLANK:	13	BLANK:	12	BLANK:	9	BLANK:	16

ROW NO:26

PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	5	CHECK:	3	CHECK:	3	CHECK:	4	CHECK:	2	CHECK:	1
OHS:	1	OHS:	2	OHS:	0	OHS:	0	OHS:	4	OHS:	1
BLANK:	12	BLANK:	13	BLANK:	14	BLANK:	14	BLANK:	12	BLANK:	16

Row NO: 27

PLUS:	3	PLUS:	2	PLUS:	1	PLUS:	1	PLUS:	2	PLUS:	0
CHECK:	3	CHECK:	4	CHECK:	4	CHECK:	5	CHECK:	6	CHECK:	1
OHS:	1	OHS:	0	OHS:	1	OHS:	0	OHS:	1	OHS:	2
BLANK:	11	BLANK:	12	BLANK:	12	BLANK:	12	BLANK:	9	BLANK:	15

APPENDIX G

DESIGN AGENCY QUESTIONNAIRE

RESULTS

DESIGN AGENCY QUESTIONNAIRE

RESULTS

. COMPUTER TECHNOLOGY AND DESIGN AGENCY FUNCTIONS

CROSS SUMMARY FOR ALL FILES OF TYPE 1

ROW NO: 1

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	1	2	0	0	0	0
CHECK:	0	1	0	0	0	0
MINUS:	0	0	0	0	0	0
NEW:	0	0	0	0	0	0
FUTURE:	1	0	0	0	0	0
BLANK:	2	1	4	4	4	4

ROW NO: 2

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	0	0	0	0	0	0
CHECK:	0	0	0	0	0	0
MINUS:	0	0	0	0	0	0
NEW:	0	0	0	0	0	0
FUTURE:	0	0	0	0	0	0
BLANK:	4	4	4	4	4	4

ROW NO: 3

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	0	2	0	0	0	0
CHECK:	3	1	0	0	0	0
MINUS:	0	0	0	0	0	0
NEW:	0	0	0	0	0	0
FUTURE:	1	0	1	1	0	0
BLANK:	0	1	3	3	4	4

ROW NO: 4

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	0	1	0	0	0	0
CHECK:	2	1	0	0	0	0
MINUS:	0	0	0	0	0	0
NEW:	0	0	0	0	0	0
FUTURE:	1	0	0	0	0	0
BLANK:	1	2	4	4	4	4

ROW NO: 5

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	0	2	0	0	0	0
CHECK:	3	1	0	0	0	0
MINUS:	0	0	0	0	0	0
NEW:	0	0	0	0	0	0
FUTURE:	1	0	0	0	0	0
BLANK:	0	1	4	4	4	4

ROW NO: 6

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	0	0	0	0	0	0
CHECK:	3	0	0	0	0	0
MINUS:	0	0	0	0	0	0
NEW:	0	0	0	0	0	0
FUTURE:	1	0	0	0	0	0
BLANK:	0	4	4	4	4	4

ROW NO: 7

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	1	0	0	0	0	0
CHECK:	1	0	0	0	0	0
MINUS:	0	0	0	0	0	0
NEW:	0	0	0	0	0	0

FUTURE:	1	0	0	1	0	0
BLANK:	1	4	4	3	4	4

ROW NO: 8

PLUS:	0	0	0	0	0	0
CHECK:	0	0	0	0	1	0
MINUS:	0	0	0	0	0	0
NEW:	0	0	0	0	1	0
FUTURE:	0	0	0	0	0	0
BLANK:	4	4	4	4	2	4

ROW NO: 9

PLUS:	0	0	0	0	0	0
CHECK:	1	0	0	0	0	0
MINUS:	0	0	0	0	0	0
NEW:	0	0	0	0	0	0
FUTURE:	1	0	0	0	1	0
BLANK:	2	4	4	4	3	4

ROW NO: 10

PLUS:	0	0	0	0	0	0
CHECK:	1	0	0	0	0	0
MINUS:	0	0	0	0	0	0
NEW:	0	0	0	0	0	0
FUTURE:	1	0	0	0	1	0
BLANK:	2	4	4	4	3	4

ROW NO: 11

PLUS:	0	0	0	0	0	0
CHECK:	0	0	0	0	0	0
MINUS:	0	0	0	0	0	0
NEW:	0	0	0	0	0	0
FUTURE:	0	0	0	0	0	0
BLANK:	4	4	4	4	4	4

ROW NO: 12

PLUS:	0	0	0	0	0	0
CHECK:	1	1	0	0	0	0
MINUS:	0	1	0	0	0	0
NEW:	0	0	0	0	0	0
FUTURE:	0	0	0	0	0	0
BLANK:	3	2	4	4	4	4

ROW NO: 13

PLUS:	0	0	0	0	0	0
CHECK:	0	0	0	0	0	0
MINUS:	0	0	0	0	0	0
NEW:	0	0	0	0	0	0
FUTURE:	0	0	0	0	0	0
BLANK:	4	4	4	4	4	4

ROW NO: 14

PLUS:	0	1	0	0	0	0
CHECK:	1	2	0	0	0	0
MINUS:	0	0	0	0	0	0
NEW:	0	0	0	0	0	0
FUTURE:	0	0	0	0	0	0

BLANK:	3	BLANK:	1	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:15

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	1	NEW:	1	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	1	FUTURE:	1	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	2	BLANK:	2	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO 16

PLUS:	0	PLUS:	3	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	1	CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	3	BLANK:	0	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:17

PLUS:	0	PLUS:	2	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	1	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	4	BLANK:	0	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:18

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:19

PLUS:	0	PLUS:	2	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	2	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	4	BLANK:	0	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:20

PLUS:	0	PLUS:	2	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	1	CHECK:	2	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	3	BLANK:	0	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:21

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	2	FUTURE:	0	FUTURE:	0	FUTURE:	1	FUTURE:	0	FUTURE:	0
BLANK:	2	BLANK:	4	BLANK:	4	BLANK:	3	BLANK:	4	BLANK:	4

ROW NO:22

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	2	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	2	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:23

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	2	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	2	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:24

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	3	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:25

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	1	CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	1	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	2	BLANK:	3	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:26

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	1	FUTURE:	0	FUTURE:	1	FUTURE:	0	FUTURE:	1	FUTURE:	0
BLANK:	3	BLANK:	4	BLANK:	3	BLANK:	4	BLANK:	3	BLANK:	4

ROW NO:27

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:28

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	4	BLANK:	3	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

[illegible]

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	2	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	1	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	4	BLANK:	3	BLANK:	4	BLANK:	4	BLANK:	1	BLANK:	4

ROW NO:30

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:31

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:32

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:33

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:34

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:35

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0	MINUS:	0
NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0	NEW:	0
FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0	FUTURE:	0
BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO 36 ROWS 36 - 79 ARE ALL BLANK FOR DESIGN AGENCIES

II. DESIGN AGENCY BENEFITS AND PROBLEMS

CROSS SUMMARY FOR ALL FILES OF TYPE 3: SECTION 1

ROW NO: 1

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	0	0	0	0	0	0
CHECK:	1	1	0	0	0	0
OHS:	0	1	0	0	1	0
BLANK:	3	2	4	4	3	4

ROW NO: 2

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	0	0	0	0	0	0
CHECK:	1	0	0	0	1	0
OHS:	0	1	0	0	0	0
BLANK:	3	3	4	4	3	4

ROW NO: 3

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	0	0	0	0	2	0
CHECK:	1	1	0	0	1	0
OHS:	0	0	0	0	0	0
BLANK:	3	3	4	4	1	4

ROW NO: 4

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	0	0	0	0	2	0
CHECK:	0	0	0	0	0	0
OHS:	0	0	0	0	0	0
BLANK:	4	4	4	4	2	4

ROW NO: 5

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	2	0	0	0	0	0
CHECK:	1	1	0	0	1	0
OHS:	0	0	0	0	0	0
BLANK:	1	3	4	4	3	4

ROW NO: 6

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	2	1	0	0	0	0
CHECK:	0	1	0	0	0	0
OHS:	0	0	0	0	1	0
BLANK:	2	2	4	4	3	4

ROW NO: 7

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	2	2	0	0	0	0
CHECK:	1	1	0	0	1	0
OHS:	0	0	0	0	0	0
BLANK:	1	1	4	4	3	4

ROW NO: 8

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	0	0	0	0	0	0
CHECK:	1	0	0	0	0	0
OHS:	0	0	0	0	0	0
BLANK:	3	4	4	4	4	4

[illegible]

	COL. #1	COL. #2	COL. #3	COL. #4	COL. #5	COL. #6
PLUS:	0	0	0	0	0	0

CHECK:	2	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
OHS:	0	OHS:	0	OHS:	0	OHS:	0	OHS:	0	OHS:	0
BLANK:	2	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:10

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
OHS:	0	OHS:	0	OHS:	0	OHS:	0	OHS:	0	OHS:	0
BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:11

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	1	CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	0
OHS:	0	OHS:	0	OHS:	0	OHS:	0	OHS:	0	OHS:	0
BLANK:	3	BLANK:	3	BLANK:	4	BLANK:	4	BLANK:	3	BLANK:	4

ROW NO:12

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
OHS:	0	OHS:	0	OHS:	0	OHS:	0	OHS:	0	OHS:	0
BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:13

PLUS:	1	PLUS:	1	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
OHS:	0	OHS:	0	OHS:	0	OHS:	0	OHS:	0	OHS:	0
BLANK:	2	BLANK:	3	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:14

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	2	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
OHS:	0	OHS:	0	OHS:	0	OHS:	0	OHS:	0	OHS:	0
BLANK:	2	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

ROW NO:15

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
OHS:	0	OHS:	0	OHS:	0	OHS:	0	OHS:	0	OHS:	0
BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4	BLANK:	4

CROSS SUMMARY FOR ALL FILES OF TYPE 3: SECTION 2

COL. #1 COL. #2 COL. #3 COL. #4 COL. #5 COL. #6

ROW NO:16

PLUS:	1	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	2	CHECK:	3	CHECK:	0	CHECK:	0	CHECK:	2	CHECK:	0
OHS:	0	OHS:	1	OHS:	0	OHS:	0	OHS:	1	OHS:	0
BLANK:	1	BLANK:	0	BLANK:	4	BLANK:	4	BLANK:	1	BLANK:	4

ROW NO:17

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	3	CHECK:	2	CHECK:	0	CHECK:	0	CHECK:	2	CHECK:	0
OHS:	0	OHS:	2	OHS:	0	OHS:	0	OHS:	1	OHS:	0
BLANK:	1	BLANK:	0	BLANK:	4	BLANK:	4	BLANK:	1	BLANK:	4

ROW NO:18

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	1	CHECK:	3	CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	0
OHS:	2	OHS:	1	OHS:	0	OHS:	0	OHS:	2	OHS:	0
BLANK:	1	BLANK:	0	BLANK:	4	BLANK:	4	BLANK:	1	BLANK:	4

ROW NO:19

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	1	CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
OHS:	2	OHS:	3	OHS:	0	OHS:	0	OHS:	3	OHS:	0
BLANK:	1	BLANK:	0	BLANK:	4	BLANK:	4	BLANK:	1	BLANK:	4

ROW NO:20

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	3	CHECK:	2	CHECK:	0	CHECK:	0	CHECK:	2	CHECK:	0
OHS:	0	OHS:	2	OHS:	0	OHS:	0	OHS:	1	OHS:	0
BLANK:	1	BLANK:	0	BLANK:	4	BLANK:	4	BLANK:	1	BLANK:	4

ROW NO:21

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	3	CHECK:	2	CHECK:	0	CHECK:	0	CHECK:	2	CHECK:	0
OHS:	0	OHS:	2	OHS:	0	OHS:	0	OHS:	0	OHS:	0
BLANK:	1	BLANK:	0	BLANK:	4	BLANK:	4	BLANK:	2	BLANK:	4

ROW NO:22

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0
CHECK:	1	CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	0
OHS:	2	OHS:	3	OHS:	0	OHS:	0	OHS:	1	OHS:	0
BLANK:	1	BLANK:	0	BLANK:	4	BLANK:	4	BLANK:	1	BLANK:	4

ROW NO:23

PLUS:	0	PLUS:	1	PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0
CHECK:	2	CHECK:	2	CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	0
OHS:	1	OHS:	1	OHS:	0	OHS:	0	OHS:	1	OHS:	0
BLANK:	1	BLANK:	0	BLANK:	4	BLANK:	4	BLANK:	1	BLANK:	4

ROW NO:24

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
OHS:	3	OHS:	2	OHS:	0	OHS:	0	OHS:	2	OHS:	0
BLANK:	1	BLANK:	1	BLANK:	4	BLANK:	4	BLANK:	2	BLANK:	4

ROW NO:25

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
OHS:	3	OHS:	3	OHS:	0	OHS:	0	OHS:	2	OHS:	0
BLANK:	1	BLANK:	1	BLANK:	4	BLANK:	4	BLANK:	2	BLANK:	4

NO:26

PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0	PLUS:	0
CHECK:	1	CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	0	CHECK:	0
OHS:	1	OHS:	1	OHS:	0	OHS:	0	OHS:	1	OHS:	0
BLANK:	2	BLANK:	2	BLANK:	4	BLANK:	4	BLANK:	3	BLANK:	4

ROW NO:27

PLUS:	2	PLUS:	1	PLUS:	0	PLUS:	0	PLUS:	1	PLUS:	0
CHECK:	1	CHECK:	1	CHECK:	0	CHECK:	0	CHECK:	1	CHECK:	0
OHS:	0	OHS:	1	OHS:	0	OHS:	0	OHS:	1	OHS:	0
BLANK:	1	BLANK:	1	BLANK:	4	BLANK:	4	BLANK:	1	BLANK:	4